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ECO

Energy Conservation and Commercialization Project

A Program of USAID, Ministry of Power and ICICI

Report On Training Course on Measurement & Verification Protocol for Energy Efficiency Projects

December 2000

Activity 3
Milestone 3A

Implemented by:

Nexant Inc., *1D II Parkwood Estate, Rao Tula Ram Marg, New Delhi 110 022.*
Tel: +91 11 6188816, +91 11 6181376. Fax: +91 11 6190022. email:nexant@vsnl.com

Nexant Inc., *408 Dalamal Tower, Nariman Point, Mumbai 400 021*
Tel: +91 22 2884554, +91 22 2825869. Fax: +91 22 2884555. email:nexantm@vsnl.net

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Preface

This report is part of the deliverable for Milestone 3A, Conduct 2 training courses on Measurement and Verification (M&V) protocols, of the ECO project. The report covers work done under this Milestone from September 2000 through December 2000.

The ECO project is being implemented by Bechtel National Inc (Nexant Inc) under a USAID contract, LAG-I-00-98-0000. This contract has been issued by the USAID Mission in New Delhi as a part of the IQC (Indefinite Quantity Contract) currently in place through USAID's Global Bureau. The project contract was signed on February 29, 2000, and continues through December 2003.

Main Training Course Report

1.0 Introduction

A three-day training course was held (at two different locations) within the context of the ECO project. The ECO project, in the main, aims to promote widespread commercialization of energy efficiency technologies and services in India by assisting stakeholders and institutions that are involved in developing, designing, constructing, implementing and operating energy efficiency projects ("Markets" component of ECO project), and by assisting government agencies and institutions in creating a supportive market environment for the commercialization of energy efficiency ("Policy" component of the ECO project).

The training course forms an integral part of the larger activity which is under the "Markets" component of the ECO project, and which aims to provide support to energy efficiency service industry. The specific purpose of these two training courses was to discuss in technical detail how the existing protocols are currently being applied to energy-efficiency projects (primarily in the U.S.) and how they can serve to mitigate project risk by making clear the allocation of risk in performance contracts.

The training course, entitled "Training Course on M&V protocol for energy efficiency projects" was held as scheduled in Mumbai on 6-8 December and in New Delhi on 12-14 December 2000, under joint responsibility of Nexant, Schiller Associates and local subcontractors Intesco Asia Limited. Both sessions of the training course, which had identical content, achieved or exceeded the minimum attendance levels and were very well received by participants. The training course participant profile, structure, conclusions and recommendations, lessons learned and further recommendations, and feedback from participants are summarized below.

2.0 Participant Profile

The training course held in Mumbai was attended by 23 participants, while the training course held in New Delhi had 17 participants. This met the target class size, which was intended to have a minimum of 15 at each location. While detailed list of participants is enclosed in Section C, summary profile has been provided in the Table below.

These training course sessions were intended to attract a broad range of participants, including representatives from ESCOs, consulting firms, financial institutes, end-users, private utilities, and government ministries. It was felt that these were the people and decision-makers that would be most receptive to the ideas being promoted here. By including end-users and financial institutes, it was felt that all parties could see the benefit of increased measurement & verification standards.

Majority of the participants were from ESCOs, practicing energy consultants and end-user segments. This participant profile helped in having lively and engaging discussions, especially during case study and group exercise sessions.

Table Showing Participant profile

Category	Number of Participants : Mumbai	Number of Participants : New Delhi
ESCOs	6	1
Energy Efficiency Consultants/Auditors	7	7
Industry Associations	1	1
Policy Makers	0	1
Institutions/NGOs	0	2
Financial Institutions	3	0
End-Users	3	2
Utility	2	1
Others	1	2
Total	**23**	**17**

Marketing of the training course was by invitation. As mentioned earlier, the audience specifically targeted were: ESCOs, end-users, financial institutes, utilities, policy makers, and energy efficiency consultants. Invitee and attendance lists from previous ECO workshops and training courses and a Council of Energy Efficiency Companies (CEEC) database provided the initial contact point. Clients of major ESCOs, and firms/companies short listed under national energy conservation award scheme were also targeted to enhance end-user participation. In addition, individuals and firms from industry associations, academic/research institutions & NGOs, were also invited for the two training course events. Nexant handled training course marketing and logistical aspects.

3.0 Training course Structure & Report on the Two Training course Sessions

The course at each location included three elements. The first consisted of theoretical inputs, provided through lecture inputs by Schiller Associates and Intesco Asia Limited, on M&V approaches and their applicability to industrial, commercial and residential sector energy efficiency projects. Theoretical inputs were supplemented by case study presentations and discussions. Combination of both, Indian and US case studies from the industrial, commercial and residential sectors were presented and discussed. Learning achieved through theory and case studies was further strengthened by providing the participants hands on experience of M&V process through group exercises from the industrial, commercial and residential sector energy efficiency projects.

As mentioned earlier, one-day workshop sessions on M&V: needs and issues were conducted in Mumbai and New Delhi one day prior to these three day training course on M&V protocols. The basic aim of these workshop and training sessions was to introduce the participants with the International Performance Measurement & Verification Protocols (IPMVP) and to provide initial training on established M&V approaches with a view to sensitize all interested parties into the benefits of more rigorous savings estimation in order to make energy-efficiency projects appear as attractive financial investments instead of construction-lending projects

Keeping in mind the proximity of the two events (training courses and workshops), the training course sessions were carefully structured to provide technical details on how the existing protocols are currently being applied to energy-efficiency projects (primarily in the U.S.) and how they can serve to mitigate project risk by making clear the allocation of risk in performance contracts. However, because of the proximity of the two events (workshops and training courses), contrary to initial expectations, many of the participants registered for both events. This required a small change in the agenda to reduce the amount of redundant information presented, but also created an opportunity to present new material. Added to the training sessions were discussions of how to measure the performance characteristics of typical equipment and demonstrations of common M&V instrumentation and software used in the U.S. ESCO industry. The added material was well-received and indicated significant interest in these areas. Because these presentations were somewhat impromptu, they were not included in the handout materials. Subsequently, however, the handouts were reproduced and handed over to the participants.

The assumption was that all who attended understood the M&V concept, concepts of performance contracting (project payments from proven savings) and had some engineering background. Feedback from the participants during the sessions indicated that this was not always the case, so additional time was spent explaining such concepts as what M&V is, what performance contracting is and how financing works under such arrangements. The backgrounds and experiences of the participants were different between the two cities. Both of these factors contributed to different levels of participation and enthusiasm between the two cities, with Mumbai having the more involved participants.

Report on the Two Training courses

The general presentation format offered in Mumbai was followed in New Delhi. In New Delhi, additional inputs on performance contracting and what M&V is, were also provided. In addition, a lecture on IPMVP by Dr. Satish Kumar of Lawrence Berkley National Laboratory was included in the New Delhi course. Mr. Mark Stetz from Schiller Associates and Mr. R. Vasu and Mr. R. Kumar from Intesco Asia acted as the main resource persons.

Following topics were discussed in the training course:

Day 1

- Overview of savings uncertainty and project risk
- Explanation of how to use measurements to define baseline and project performance
- Overview of common M&V techniques (Delhi only)
- Display of common M&V equipment and software
- Case studies (3) from industrial sector
- Group exercises on industrial sector

Day 2

- Presentations of industrial sector group exercises
- Case studies (3) from commercial sector
- Group exercises on commercial sector

Day 3

- Presentations of commercial sector group exercise
- Case studies (3) from residential sector
- Presentations from participants on their project experiences (Mumbai only)
- Open discussion on adopting M&V protocols

For the group exercises, the participants were divided into groups of 3-5 people and asked to develop an M&V approach for hypothetical projects. This forced them to understand the problem, identify the factors that affected energy savings, and develop a M&V strategy that would identify the savings. Groups were asked to make presentations of their solutions and these were discussed in open sessions, with the faculty acting as moderators. At the end of the discussion sessions, the faculty presented their views on possible M&V approaches to various case problems discussed.

4.0 Conclusions and Recommendations

From the presentations and comments offered during these two workshops, the following conclusions and recommendations have been drawn.

These sessions were developed with the assumption that the participants were familiar with concepts in the energy-services industry. Immediate feedback in the Delhi session indicated this was not the case, so additional time was spent explaining what performance contracting is and how financing works under such arrangements. Future sessions should include more discussion of project financing and performance contracting.

As one of the exercises to encourage thinking about risk assessment and risk mitigation, the participants were divided into small groups (3-5 people) and asked to develop M&V approaches for hypothetical projects in the commercial and industrial sectors. In some cases, the hypothetical exercises were ambiguous (originally thought to be a benefit) or technically demanding, which required too much explanation and detracted from the real task at hand. Future exercises of this sort should contain more information (reduce ambiguity), not be so technically demanding (not all participants are engineers), and be more specific to Indian commercial and industrial practices.

During the training sessions, reference to a 'standard lighting table' was made. This is a collection of information on typical fixture arrangements (lamp & ballast combinations) that contains average fixture powers. Such a table can be used to standardize savings calculations, reduce measurement costs, and increase savings estimates reliability. While this idea received only lukewarm reception, it might be a useful exercise for someone to compile this information on common fixture types found in India.

Based on the feedback and response from the participants, a future three-day training session agenda might include the following topics:

Day 1: Overview of M&V (could also be considered the 'Executive Summary')

- Introduction to performance contracting and project financing
- Performance Contracting project risk and how M&V treats such risk
- Additional benefits of M&V practices
- Introduction to IPMVP concepts and language
- Applications of IPMVP methods
- Case studies from the commercial sector
- Group exercise with real commercial sector example projects

Day 2: Basic M&V Methods

- Presentation of group exercise results
- Developing an M&V Plan
- Showing compliance with IPMVP and India-specific protocols
- Defining baseline conditions
- Using measurements to characterize equipment
- Introduction to statistical concepts I (precision, confidence, sample sizes, uncertainty)
- Proper application of stipulations with Option A
- Case studies from the industrial sector
- Group exercise with real industrial sector example projects

Day 3: Advanced M&V Methods

- Presentation of group exercise results
- Demonstration of common metering and data acquisition equipment
- Typical applications of Option B methods
- Introduction to statistical concepts II (bin analysis, linear regression analysis)
- Typical applications of Option C methods
- Demonstration of building simulation software
- Typical applications of Option D methods
- Determining M&V costs and cost-effectiveness

5.0 Lessons Learned and Further Recommendations

Results from these workshops and training sessions indicate a real need for additional training in the areas of performance contracting, project financing, and measurement & verification activities. Feedback from these sessions have application to future tasks, especially Milestone 3C (ESCO development).

Potential ESCO development seminars should include measurement and verification as part of the program, but not to the exclusion of other elements. (Potential M&V topics that should be included are shown in the previous section.) Other materials to be included are project financing and arranging, efficient technology information (similar to Milestone 4A, but condensed), and customer education (how the ESCO/consultant can educate their customers). Customer education seems to be a barrier to further market development and should be emphasized.

Feedback from the participants indicated that shorter programs would be desirable and suggested that 3 days would have been appropriate for the material covered.

Attendance at workshops and training sessions is likely to be inversely proportional to their length because of the need to operate and maintain a business. Had these sessions been 5 days in length instead of 3 or 4, attendance probably would have suffered.

In the event sessions run longer than three days, there may be some value to segregating participants by background or interest so as not to bore those with legal or financial backgrounds with engineering details. Likewise, spending too much time on project financing may not be the top interest among engineers and consultants. Development of a focused lesson plan is key to maintaining interest.

The group exercises proved to be a useful component of the training sessions, especially when consultants could be grouped with financial institute representatives. This made the exercise more real because of the balanced perspectives. Feedback indicated that these were valuable because of their relevance.

6.0 Participant Feedback

A very elaborate questionnaire was designed to obtain participant feedback on the two training courses. The questionnaire it self was a combination of structured and open-ended questions. Structured as well as open ended responses were sought on aspects such as, Training Course content and structure, whether goals met, quality of resource persons/faculty, delivery methodology, venue, administrative arrangements, handout material quality and usefulness, level of skill achieved, confidence in applying the learned skill, overall satisfaction level with the course and publicity and invitations; open ended responses were sought on which part of the course was liked most, which part needed improvement, and a section on general comments and suggestions. A sample feedback form, along with summaries of the responses from each of the two Training Courses has been enclosed in Section D. The principal conclusions provided from these summaries include the following:

Overall satisfaction with course

Structured as well as open-ended responses were sought from participants on this aspect. As far as the structured part is concerned, the participants in both, Mumbai and New Delhi provided an average rating of 4.3 on a 5 point scale (rating of 1 being very poor and rating of 5 being very good). On the open-ended side, the respondents mostly reported very high level of satisfaction with the course.

Level of knowledge of faculty

Structured as well as open-ended responses were sought from participants on this aspect. As far as the structured part is concerned, the participants in Mumbai and New Delhi provided an average rating of 4.5 and 4.6 respectively, on a 5 point scale (rating of 1 being very poor and rating of 5 being very good). On the open-ended side, the respondents mostly reported very high level of satisfaction with the knowledge and experience of the faculty, especially their knowledge about practical aspects of the applicability of M&V.

How does level of skill achieved by yourself compare with your expectation?

Structured as well as open-ended responses were sought from participants on this aspect. As far as the structured part is concerned, the participants in Mumbai and New Delhi provided an average rating of 3.8 and 4.0 respectively, on a 5 point scale (rating of 1 being Lower and rating of 5 being Higher). This shows that the course has met expectation level of majority of the participants. On the open-ended side, the respondents mostly reported that they are now better equipped than before in dealing with M&V issues.

What is your level of confidence in regards to your use of the new skills?

Structured as well as open-ended responses were sought from participants on this aspect. As far as the structured part is concerned, the participants in Mumbai and New Delhi provided an average rating of 3.6 and 4.0 respectively, on a 5 point scale (rating of 1 being Low and rating of 5 being High). This shows that the course has really helped in enhancing the skill level of the participants. On the open-ended side, the respondents mostly reported moderate to good competence with regards to use of new skills.

Most valuable parts of the course

Case studies and group exercises, presentation by Dr. Satish Kumar of Lawrence Berkley National Laboratory, information provided on web sites from where further information can be gathered, and learning about the instruments available for measurements and software available for data processing and designing were reported as the most valuable part of the program.

Parts of the course that need improvement

Emphasis on industrial sector, fuels other than electricity, emphasis on application of M&V through detailed group exercises, reduced number of days for the training courses, and inclusion of real live case studies, instead of class room exercises, like site/factory visits, were reported as some of the areas where improvements can be brought in.

General Comments

Ensuring larger participation from end-usersand financial community (especially, commercial and cooperative banks), exploring the feasibility of stocking some of the common software used in M&V (a kind of library), providing more awareness about performance contracting and ESCO concept, attempting more 'indianization' of the course, and proper publicity were mentioned as some of the general comments by course participants.

Program
Course on
Measurement & Verification Protocol for Energy Efficiency Projects

Date: **6 - 8, December 2000**
Venue: **Hotel Prsident, Mumbai**

Day 1

0930	Registration	
	Inaugural Session	
1000 – 1020	Welcome, Participant and Faculty Introduction	Nexant Inc.
1020 – 1045	Overview of ECO Project and Course Introduction	Nexant, Inc.
1045 – 1100	TEA BREAK	
1100 –1215	M&V an Introduction: Need, Scope, Objectives, Audience, Benefits and Options	INTESCO Asia : Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1215 - 1330	Using Measurements	Schiller Associates: Mr. Mark Stetz
1330 – 1430	LUNCH	
1430 – 1600	M&V Protocols – **Industrial** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1600 – 1615	TEA BREAK	
1615 - 1700	Salient Features of Draft Model M&V Protocol – **Industrial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar

Day 2

1000 - 1045	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Industrial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1045 – 1100	TEA BREAK	
1100 – 1330	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Industrial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1330 – 1430	LUNCH	
1430 – 1545	M&V Protocols – **Commercial** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1545 – 1600	TEA BREAK	
1600 - 1700	Salient Features of Draft Model M&V Protocol – **Commercial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar

Day 3

1000 – 1045	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Commercial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1045 – 1100	TEA BREAK	
1100 – 1245	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Commercial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1245 – 1330	M&V Protocols – **Residential** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1330 – 1415	LUNCH	
1415 – 1445	Salient Features of Draft Model M&V Protocol – **Residential** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar
1445 – 1530	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Residential** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1530 – 1700	Discussion on Day 3, Feed Back and Course Evaluation	Nexant, INTESCO Asia and Schiller Associates

Program
Course on
Measurement & Verification Protocol for Energy Efficiency Projects

Date: **12-14, December 2000**
Venue: **India Habitat Centre, New Delhi**

Day 1

0930	Registration	
	Inaugural Session	
1000 – 1020	Welcome, Participant and Faculty Introduction	Nexant Inc.
1020 – 1045	Overview of ECO Project and Course Introduction	Nexant, Inc.
1045 – 1100	TEA BREAK	
1100 –1145	M&V an Introduction: Need, Scope, Objectives, Audience, Benefits and Options	INTESCO Asia : Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1145 – 1300	What is Measurement & Verification	Schiller Associates: Mr. Mark Stetz
1300 – 1400	LUNCH	
1400 -1445	Using Measurements	Schiller Associates: Mr. Mark Stetz
1445 – 1545	M&V Protocols – **Industrial** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1545 – 1600	TEA BREAK	
1600 – 1700	Salient Features of Draft Model M&V Protocol – **Industrial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar

Day 2

1000 – 1045	M&V Protocols – **Commercial** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1045 – 1100	TEA BREAK	
1100 – 1145	M&V Protocols – **Commercial** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1145 - 1300	Salient Features of Draft Model M&V Protocol – **Commercial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar
1300 – 1400	LUNCH	
1400 - 1515	M&V Protocols – **Residential** Sector, including Case Studies	Schiller Associates: Mr. Mark Stetz
1515 - 1530	TEA BREAK	
1530 – 1700	Salient Features of Draft Model M&V Protocol – **Residential** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar

Day 3

0930 - 1030	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Industrial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1030 - 1045	TEA BREAK	
1045 - 1145	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Commercial** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1200 - 1300	IPMVP 2000 and its Relevance to Indian Industry	Guest Lecture by Mr. Satish Kumar, Lawrence Berkley National Laboratory, USA
1300 - 1400	LUNCH	
1400 - 1500	Hand on Exercise for Participants/Participant Groups/Tutorial - M&V in **Residential** Sector	INTESCO Asia: Mr. R. Vasu & Mr. R. Kumar and Schiller Associates: Mr. Mark Stetz
1500 - 1515	TEA BREAK	
1515 - 1630	Discussion on Day 3, Feed Back and Course Evaluation	Nexant, INTESCO Asia and Schiller Associates

ECO PROJECT: MILESTONE 3A
Training Course on M&V for Energy Efficiency Projects
6 - 8, December 2000: Mumbai
LIST OF PARTICIPANTS

S. No.	NAME & DESIGNATION	COMPANY'S NAME	TELEPHONE #	FAX
1.	P. Muthukumaraswamy Asst. Director sitra@vsnl.com	The South India Textile Research Association (SITRA) Coimbatore 641014	0422-574367	0422-571896
2.	V. Gopalan, CEO gopalan755@hotmail.com	Savenergy Products A1, 504 Happy Valley Homes Tikuji-ni-wadi Road Mampada, Thane (West) Pin 400 607	5383765/ 5385256	5385256
3.	M.V. Ananthakrishna Executive Director ananthakrishna@vsnl.com	M K Raju Consultants Private Limited 16, Srinagar Colony, Temple Avenue Chennai 600 015	2351151	2351070
4.	Rajashekar P. Mandi, Engineering Officer cprit@vsnl.com	CPRI P.B. No. 3506, Sreekariyam Thiruvananthapuram 695 017	0471 596004	0471 599687
5.	S.K. Pasale, Director Sheshipasale@hotmail.com	Devki Energy Consultancy Private Limited A-8, La Serena, Orlem, Malad West Mumbai 400 064	8823048	8441236
6.	J.D. Dhumal Asst. VP dhumalj@icici.com	ICICI Limited ICICI Towers, Bandra-Kurla Complex Bandra (East), Mumbai 400 051	6536475	6531268 6531269

S. No.	NAME & DESIGNATION	COMPANY'S NAME	TELEPHONE #	FAX
7.	Priyanka Roy priyanka@icici.com	ICICI Limited ICICI Towers, Bandra-Kurla Complex Bandra (East), Mumbai 400 051	6536486	6531268 6531269
8.	Mahesh Patankar mahesh@bom2.vsnl.net.in	Environment & Development Consultants Dwaraka, Pushpadhanwa Society, Nahur Road Mulund (West), Mumbai 400 080	5686876 5679245	
9.	S.K. Vichare Divisional Manager svichare@thermaxindia.com	Thermax EPS Limited SAI Chambers, 15 Mumbai-Pune Road Wakdewadi, Pune 411 003	5511010 5511381	5511144
10.	V.K.A. Unni Sr. Manager-Eng. vkaunni@thermaxindia.com	Thermax EPS Limited SAI Chambers, 15 Mumbai-Pune Road Wakdewadi, Pune 411 003	5511010	5511144
11.	M. Chittawar Managing Director seemil@nagpur.dot.net.in	Seetech Solutions Pvt. Ltd. h-001, Sanchayani Prestige Swavalambi Nagar, Nagpur 440 022	0712264433	0712-265816
12.	R.G. Deshmukh Consultant		8743087	
13.	B.R.U. Nayar Deputy Manager (Energy) Pcrawr@bom3.net.in	PCRA, Western region C/5, Keshava Bldg. Gr. Floor Bandra Kurla Complex, Mumbai 400 051	6542181/587	6542470
14.	Mukesh Patidar Engineer – R&D mukesh.Patidar@in.abb.com	ABB Ltd. (CTR) Maneja, Vadodara 390 013	0265-604439 0265 642141	640718
15.	Manoj Nambiar Sr. Eng. (Projects) mpmanoj@yahoo.com	Saha Sprague, Ltd. N.805, Manipal Centre Dickenson Rd., Bangalore 560 042	0805595463	5595463

15

S. No. NAME & DESIGNATION	COMPANY'S NAME	TELEPHONE #	FAX
16. M S Balasundaraj Dixit General Manager (Research) bdixit@sahasprague.com	Energy Venture Capital Limited 1st Floor, 266 Dr. Anne Besant Road Worli, Mumbai 400 025	4301969 4210234	
17.Rahul Walawalkar Rahul.walawalkar@tatainfotech.com	Tata Infotech Limited Products Division, SEEPZ Andheri (E), Mumbai 400096	8291261	8290214
18. C.S. Rao Sr. Engr. Tech. Services	IPCL-MGCC Nagothane 402 125	0214422280 Extn. 2710	0214423067
19. Sachin Kumar, Sr. Engr.	BSES Ltd., Supply Division Electricity House, Santa Cruz (E) Mumbai 400 055	6100505	6112858 6170994
20. C. Tanveer Ahmed Sr. Engineer	BSES Ltd. Supply Division Electricity House, Santa Cruz (E) Mumbai 400 055	6177397	6112858 6170994
21. Vijay Gambhire vijayg@rpgnet.com	RPG Enterprises Ceat Mahal, 463, A.B. Road Worli, Mumbai 22	4930621	497210
22. Zahira Banu, Manager zahira@ifcimumbai.com	IFCI, Earnest House NP, Mumbai 400 021	2835373	2851016
23. Mr. T. Sankarnarayanan Sr. Deputy Director npcmum@vsnl..net	National productivity Council Novelty Chambers, Grant Road	3071322 3002924	3073323

ECO PROJECT: MILESTONE 3A

Training Course on M & V Protocols for Energy Efficiency Projects
12-14 December, 2000: New Delhi
LIST OF PARTICIPANTS

1. Mr. H.C. Hans, Group Manager
   National Council for Cement & Building Material
   34 KM Stone, Delhi Mathura Road
   Ballabhgarh (Haryana)
   Tel: 0129-5242051
   Fax: 0129-5242100

2. Mr. Biswambhare Pande
   Assistant Engineer, NDMC
   New Delhi Municipal Council
   Pragati Bhawan
   RPD Division, 6th Floor
   New Delhi
   Tel: 011-3346545

3. Dr. Naval Karrir
   PCRA
   New Delhi
   Tel : 011-3310006
   Fax : 011-3715244

4. Dr. S. Renganarayanan
   Institute for Energy Studies
   Anna University
   Chennai 600 025
   Tel: 044-2300875
   Fax: 044-2300121

5. Mr. S.K. *Dutta*
   12 B, Amrita Lal Bose Street
   Calcutta 700 005
   Tel: 033-555-316
   Fax: 033-*5551005*
   Email: skduttape@hotmail.com

6. Mr. Ashutosh Saxena, Manager
   National Council for Cement & Building Material
   New Delhi
   Tel: 011-5242051
   Fax: 011-5242100

7. Mr. Sukumar Barman
   Deputy Manager
   National Council for Cement & Building Material
   New Delhi
   Tel: 011-5242051
   Fax: 011-5242100

8. Mr. Laxmindra Mohan, Consultant
   DCM Shriram Consolidated Ltd
   Kanchanjunga Building
   Barakhamba Road, Connaught Place
   New Delhi
   Tel: 011-3316801

9. Mr. N.K. Goyal, Consultant
   Essen Energy, Indore
   Tel: 0731-551721
   Fax: 0731-553286
   Email: essenenergy@vsnl.com

10. Mr. Tarun Batra
    Assistant Engineer
    NDMC, Palika Kendra
    New Delhi
    Tel: 011-3361006
    Email: batra_t@yahoo.com

11. Mr. K.R. Goyal, Sr. Consultant
    National Export Organization
    2D, Deepa Complex, 10-I.P. Extension
    Delhi 110 092

12. Mr. S.S. R. Prasad
    ASCI, Hyderabad
    Tel: 040-3310952

13. Mr. R.P. Nagpal
    Delhi Vidyut Board
    New Delhi
    Tel: 011-6470708

14. Mr. V.P. Singh
    PHDCCI – EMC
    New Delhi
    Tel: 011-6852918

15. Mr. S. Ramaswamy
Energy Management Center
New Delhi
Tel: 011-6864867
Fax: 011-6868914

16. Dr. A. Kaupp
Energy Management Center
Tel: 011-6864867
Fax: 6868914

17. Mr. Rajesh Jain
Enhanced WAPP Systems (India) Pvt Ltd
New Delhi
Tel: 011-6123505/6897483/6133995
Fax: 011-6131911
Email: wapp@del3.vsnl.net.in

Participant Feedback

A very elaborate questionnaire was designed to obtain participant feedback on the two training courses. The questionnaire it self was a combination of structured and open-ended questions. Structured as well as open ended responses were sought on aspects such as, Training Course content and structure, whether goals met, quality of resource persons/faculty, delivery methodology, venue, administrative arrangements, handout material quality and usefulness, level of skill achieved, confidence in applying the learned skill, overall satisfaction level with the course and publicity and invitations; open ended responses were sought on which part of the course was liked most, which part needed improvement, and a section on general comments and suggestions. A sample feedback form, along with summaries of the responses from each of the two Training Courses has been enclosed.

Structured Responses:

Enclosed table shows participant feedback on Mumbai and New Delhi workshops to various questions listed in the Table under the heading "criteria". The responses were sought on 5 point scale and the average rating obtained against each of the criteria shown in the enclosed table. It can be seen that for all the 12 criteria, the average rating is above 3.3. The overall satisfaction level for the training is rated at 4.3 points by Mumbai as well as New Delhi participants.

Responses to Open Ended Questions

Responses to the open ended questions have been compiled and tables showing sample responses from the participants at two locations have been enclosed.

ECO PROJECT : FEED BACK

6-8 DECEMBER, 2000: Mumbai & 12-14 DECEMBER, 2000 : New Delhi

Criteria	Scale Ends		Average Rating on a Five Point Scale For MUMBAI COURSE	Average Rating on a Five Point Scale For DELHI COURSE
How would you rate this course for the content and structure of the course in meeting your objectives?	1 = Very Poor;	5 = Very Good	4.2	4.4
The level of program material was?	1 = Very Poor;	5 = Very Good	4.6	4.0
The usefulness of the material presented was?	1 = Limited;	5 = Considerable	4.3	4.5
What was the level of knowledge of your Faculty?	1 = Very Poor;	5 = Very Good	4.5	4.6
Were the Course Objectives met?	1 = Not at all;	5 = Exceeded	3.8	3.8
The percentage of time given to practice/practical was?	1 = Too Little;	5 = Too Much	3.6	3.4
The availability of equipment was?	1 = Very Poor;	5 = Very Good	4.5	4.3
How does level of skill achieved by yourself compare with your expectation?	1 = Lower;	5 = Higher	3.8	4.0
What is your level of confidence in regards to your use of the new skills?	1 = Low;	5 = High	3.6	4.0
The Venue it self and other facilities at the venue were?	1 = Very Poor;	5 = Very Good	4.4	4.5
The Overall publicity for the course was?	1 = Very Poor;	5 = Very Good	3.3	3.3
Overall, how would you rate your satisfaction with this course?	1 = Very Poor;	5 = Very Good	4.3	4.3

ECO Project: FEED BACK
Milestone 3A (M&V Part)
Training Course on M&V Protocol for Energy Efficiency Projects
6-8 December, Mumbai

Criteria	Responses
How would you rate this course for the content and structure of the course in meeting your objectives?	1.The course covered a wide range of issues in several sectors in energy efficiency, besides M&V; 2. I am happy with content and structure, perhaps a more specialist could have addressed us.; 3. Role of utility should have been emphasized; 4. This is quite well though-out program; 5. Partially fulfilled; 6. Very clearly defined and adhered to 7. It gave us a detailed insight of M&V - importance, how to do it, minimizing /optimizing M&V costs - depending on the saving potential of the ECM
The level of program material was?	1. Fairly Exhaustive; 2.Highly intensive; 3. Most ideally suited for we participants'- Hard copies of IPMVP could have been circulated and discussions focused on these 4. Very good, Particularly DOE literature is good ; 5. First of its kind in India, particularly 6. Very good - brought out concepts clearly with examples 7. Good, but more industrial case studies would have made it better
The usefulness of the material presented was?	1. Very informative with regard to the sectors, a little too technical for a legal person like me; 2. We could now use this material for the benefit of our clients, also for disseminating information; 3. It can be utilized as per the specific requirements of the industry 4. Was good - because of relevant and practical examples
What was the level of knowledge of your Faculty?	1. The presentations and lectures were obviously backed by years of sound experience 2. Experience of 22 years and having been an energy conservationist, understood the presentations easily. 3. Faculty had hands-on experience on many E&M projects 4. Mr. Mark, Mr. Vasu and Mr. Kumar's technical inputs were good 5. They were thorough in this subject; 6. All the faculty had case studies based on their experience. This made the total program more valuable; 7. Was very good - handled all the queries effectively

ECO Project: FEED BACK
Milestone 3A (M&V Part)
Training Course on M&V Protocol for Energy Efficiency Projects
6-8 December, Mumbai

Criteria	Responses
Were the Course Objectives met?	1. I am not sure; 2. Yes, however, would like to request US AID to explore the possibility of stocking their in-house facility with various M&V related soft-ware, so that we could benefit; 3. M&V protocols' draft should have been discussed 4. Yes, in terms of global objectives; micro level - to some extent; 5. Partially fulfilled 6. Will be reflected in the protocol developed
The percentage of time given to practice/practical was?	1. Enjoyed the hands on exercises, found them lively. 2. Quite enough; 3. Sufficient enough; 4. Need a little more control for reducing the involvement of participants where not so much required; 5. Just about Okay
The availability of equipment was?	1. As expected
How does level of skill achieved by yourself compare with your expectation?	1. Being a legal person, I really did not expect to achieve any skills 2. Time spent was more than worth the while, Mark Stetz was especially good 3. In fact lot of new areas of this business; 4. Better informed than earlier
What is your level of confidence in regards to your use of the new skills?	1. Being a legal person, I really did not expect to achieve any skills 2. Good; 3. There is a need to work on the entire company getting introduced on this concept; 4. Would help in the assessment of such projects
The Venue it self and other facilities at the venue were?	1. Good ambience; 2. Adequate; 3. Venue could be any where in the suburbs; 4. OK
The Overall publicity for the course was?	1. Perhaps, there should have been better participation from Financial Institutions 2. A few engineering consultants and Architects should have been invited too. Should also have brought in Nationalized and Cooperative Banks, large power consuming industries and larger segment of industry; 3. It would have been better if more people from measurement side and user industry were present; 4. Heard it from organizers and no other source
Overall, how would you rate your satisfaction with this course?	1. The interaction of participants and faculty was very lively and encouraged exchange of information ; 2. The course was informative, but really far removed from my legal background; 3. Good; 4. Very informative; 5. Looking forward to more programs from ECO in this area; 6. Met my expectations

R3

ECO Project: FEED BACK
Milestone 3A (M&V Part)
Training Course on M&V Protocol for Energy Efficiency Projects
6-8 December, Mumbai

Criteria	Responses
Which were the most valuable parts of the course for you?	1. Understanding issues and concerns of ESCOs relating to funding of projects 2. For me, most valuable parts were the issues arising out of M&V 3. Learning about the meters available for measurement and the software available and used; 4. Information about residential sector projects; 5. Technical inputs were good 6. Mr. Mark's interaction with the participants; 7. The importance of M&V approach in energy conservation schemes in present scenario; 8. To know the type of M&V, and ECMs in the buildings; 9. Case studies and exercises; 10. An overall perspective of M&V for mitigating risk in implementing ECM; 11. Group exercises; 12. Group work/exercises & computer energy data analysis; 13. Case discussions as all of them were real life; 14. Industrial applications of M&V
Which parts would you like to see improved?	1. More specialists could address, also repetition of some topics covered in one day seminar made it difficult for some of us; 2. Clarification on role of utilities applied in Indian power scenario; 3. Case studies to cover major industries in India; 4. Reduced number of days, may be by one day at least; 5. Formulating specific options based on ECMs, e.g. lighting - one option standardized for all projects; 6. Applications of M&V protocols
Do you have any other comments or suggestions	1. Incorporate suggestions given by participants for the next course and seminar in Delhi 2. USAID/NEXANT could stock software like ENERGY 2000, BLAST, ENERGY 10, TRACE, etc; Involve following organizations in discussions/training on M&V : IITs, VJTI, UDCT, CBRI, MPEDA, EIA, EIL, RDSO, ISRO, VSSC, DAE, CVRDE (Defence); Continue dissemination of information on M&V to larger segment and bring in more experts; 3. Spread the message is more important. Keep it up 4. Some technical material like key points, thumb rules, etc. should be added like what is given in literature from FEMP, DOE; 5. The duration of four days is too long. This can be covered in 3 days; 6. More end-users should participate; 7. Would like to see the India specific protocol as soon as possible; 8. Please attempt to increase the participation from industries - manufacturing and service sector; 9. For marketing of energy efficiency products/services, only one program has been proposed during Jan-March 2001- should have more programs evenly distributed across d

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ECO Project: FEED BACK
Milestone 3A (M&V Part)
Training Course on M&V Protocol for Energy Efficiency Projects
12-14 December, 2000: New Delhi

Criteria	Responses
How would you rate this course for the content and structure of the course in meeting your objectives?	1. Nicely composed; 2. Some more case studies should be discussed which is applicable in Indian context so that one can follow that procedure; 3. More emphasis on industrial projects, looking from Indian context is needed; 4. Very sincerely conducted; 5. Some practical calculations for the establishment of baseline may be included for better understanding; 5. Towards M&VP - OK, but more important is taking industrial cases for benefit to India perspective; 6. Good exposure
The level of program material was?	1. The material needs to be arranged a bit in anticipatiuon to the invitees/participants; 2. Useful information has been provided; 3. Very educative and exhaustive; 4. More references may be provided for gathering further information; 5. OK; 6. OK
The usefulness of the material presented was?	1. Case studies were based on US conditions, but it is better also to know about innovations and methods adopting for energy conservation; 2. Very useful; 3. It was useful; 4. Great; 5. It was eye opener about the importance of M&V
What was the level of knowledge of your Faculty?	1. Well equipped, with adequate calibre; 2. Every body was experienced, but best part is open discussions when every body has shared its experience and that was good/excellent for learner like me; 3. They have done their job nicely; 4. Level of knowledge was very good; 5. Good, but would have been better if they could provide more details about industrial sector; 6. Excellent
Were the Course Objectives met?	1. Yes, adequately; 2. Most of the things have been covered, OK as per the time available.; 3. Yes; 4. Course objectives were met nicely
The percentage of time given to practice/practical was?	1. Not much; 2. Very balanced; 3. As required - the program could have been a two day program; 4. Sufficient
The availability of equipment was?	
How does level of skill achieved by yourself compare with your expectation?	1. It is just OK; 2. Considerable; 3. Many new ideas, concepts learnt during the course; 4. OK
What is your level of confidence in regards to your use of the new skills?	1. Just good enough; 2. Moderate; 3. OK
The Venue it self and other facilities at the venue were?	1. Comfortable and good; 2. Drinking water facility to be improved, moth(?)/room freshner should be arranged

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ECO Project: FEED BACK

Milestone 3A (M&V Part)
Training Course on M&V Protocol for Energy Efficiency Projects
12-14 December, 2000: New Delhi

Criteria	Responses
The Overall publicity for the course was?	1. Energy auditors and end-users not invited/represented adequately; 2. Publicity or follow-up seems to be lacking; 3. Looking at participant strength and the quality of the course and cost, more participants were needed
Overall, how would you rate your satisfaction with this course?	1. It is quite satisfactory
Which were the most valuable parts of the course for you?	1. Case studies of commercial - large buildings; 2. Presentation by Dr. Satish Kumar, also other presentations; 3. Industrial propjects coverage; 4. IPMVP; 5. Information on available web sites to find/gather further information; 6. New technology and cases in industrial apllications, presentation by Dr. Satish Kumar; 7. Different options given; 8. Case studies; 9. Dr. Satish Kumar's presentation; 10. Outlining M&V protocol, its importance and options A, B, C, D; 11. Case studies on M&V
Which parts would you like to see improved?	1. Need to associate with live real life situations, instead of class room exercises, also more time needs to be allocated for accurate case studies; 2. More dtails being provided in group assignments; 3. Industrial sector emphasis; 4. Technical systems; 5. Case studies; 6. Publicity; 7. More hands on exposure
Do you have any other comments or suggestions	1. M&V, more useful for large industries, We are just at the motivating stage in India, need more awareness.; 2. More indianisation of the program. Should be more relevant to industrial projects - gradually the emphasis could increase on the projects in commercial and residential sectors as the awareness and requirements build up.; 3. In case there is a program in future, we will like to participate; 4. Proper pubilicity for better participation, & document generation to give policy guidelines to government for better energy efficiency in the country; 5. Seminar and first day of workshop can be compressed to make it a course of shorter duration; 6. We would like to become an active member of the ECO project; 7. More programs of this nature

Vijay

From: vkaunni@THERMAXINDIA.COM
Sent: Monday, December 18, 2000 10:26 AM
To: India_m-v_cg@egroups.com
Cc: nexant@vsnl.com
Subject: M & V TRAINING AT MUMBAI

Dear Friends,
It was an excellent training session that we had between the 5th and 8th of December at Mumbai. The overall interaction of the group was excellent and encouraging free flow of information. We really got benefited with this training session and hope all the participants have the same feeling.
We thank each one of you for the success of this program. We look forward to more frequent interaction between the group for mutual benefits.
With warm regards

V.K.Anand Unni & S.K.Vichare
Thermax Energy Performance Services Limited
Pune

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ECO PROJECT: COURSE EVALUATIUON FORM

Course on Measurement & Verification Protocols for Energy Efficiency Projects

6-8 December, 2000: Hotel President – Mumbai

Dear Participant:

We value your views on how you experienced this Course. Please take a few minutes to complete this form.

1. **How would you rate this course for the content and structure of the course in meeting your objectives?**

Very Poor				Very Good
1	2	3	4	5

Comments:

2. **The level of program material was?**

Very Poor				Very Good
1	2	3	4	5

Comments:

3. **The usefulness of the material presented was?**

Limited				Considerable
1	2	3	4	5

Comments:

4. **What was the level of knowledge of your Faculty?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

5. **Were the Course Objectives met?**

Not at all				Exceeded
1	2	3	4	5

Comments:

_____

_____

6. **The percentage of time given to practice/practical was?**

Too little				Too much
1	2	3	4	5

Comments:

_____

_____

7. **The availability of equipment was?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

8. **How does level of skill achieved by yourself compare with your expectation?**

Lower				Higher
1	2	3	4	5

Comments:

_____

_____

9. **What is your level of confidence in regards to your use of the new skills?**

Low				High
1	2	3	4	5

Comments:

_____

---

10. **The Venue it self and other facilities at the venue were?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

11. **The Overall publicity for the course was?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

12. Which were the most valuable parts of the course for you?
Comments:

_____

_____

13. Which parts would you like to see improved?

Comments:

_____

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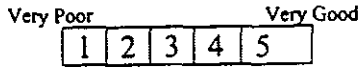
14. Overall, how would you rate your satisfaction with this course?



Comments:

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15. Do you have any other comments or suggestions?

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Thank you for your help.

ECO PROJECT: COURSE EVALUATIUON FORM

Course on Measurement & Verification Protocols for Energy Efficiency Projects

12-14 December, 2000: India Habitat Centre – New Delhi

Dear Participant:

We value your views on how you experienced this Course. Please take a few minutes to complete this form.

1. **How would you rate this course for the content and structure of the course in meeting your objectives?**

Very Poor				Very Good
1	2	3	4	5

Comments:

---

2. **The level of program material was?**

Very Poor				Very Good
1	2	3	4	5

Comments:

---

3. **The usefulness of the material presented was?**

Limited				Considerable
1	2	3	4	5

Comments:

---

4. **What was the level of knowledge of your Faculty?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

5. **Were the Course Objectives met?**

Not at all				Exceeded
1	2	3	4	5

Comments:

_____

_____

6. **The percentage of time given to practice/practical was?**

Too little				Too much
1	2	3	4	5

Comments:

_____

_____

7. **The availability of equipment was?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

8. **How does level of skill achieved by yourself compare with your expectation?**

Lower				Higher
1	2	3	4	5

Comments:

_____

_____

9. **What is your level of confidence in regards to your use of the new skills?**

Low				High
1	2	3	4	5

Comments:

_____

---

10. **The Venue it self and other facilities at the venue were?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

11. **The Overall publicity for the course was?**

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

_____

12. Which were the most valuable parts of the course for you?
Comments:

_____

_____

13. Which parts would you like to see improved?

Comments:

_____

---

14. Overall, how would you rate your satisfaction with this course?

Very Poor				Very Good
1	2	3	4	5

Comments:

_____

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15. Do you have any other comments or suggestions?

_____

_____

_____

Thank you for your help.

Monitoring & Verification of Energy Savings An Introduction

INTESCO Asia Limited

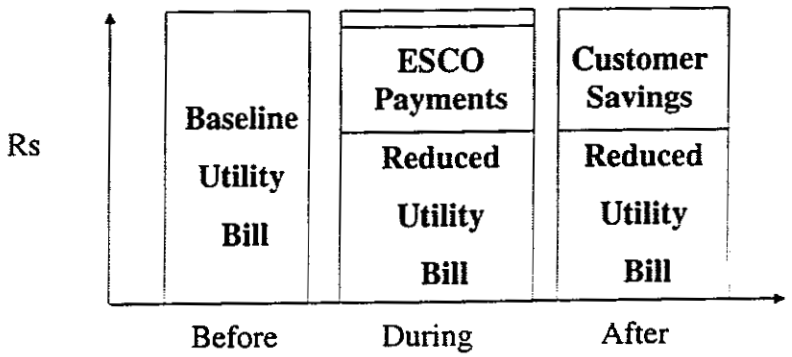
Outline

- Energy Performance contracting approach to energy efficiency projects.
- Measurement issues
- Funding issues
- Need for a Standard / Protocol
- Development of India specific M&V protocol

Energy Performance contracting (PC)

- ESCOs - Energy Service Companies
- ESCOs provide performance contracting solutions

Typical PC approach



Common Issues

- Factors affecting energy saving performance
- Non-routine baseline adjustments due to
  - addition or deletion of machinery, loads etc.
  - set-point changes

5 of 15

Measurement Issues

- How long to measure?
- Cases Option A or B.
- Expensive Calibration.
- M&V costs how much is justifiable?
- No formal procedures to identify levels of M&V that minimizes M&V cost plus uncertainty.

6 of 15

M & V Issues

(Industries)

- Base-line development.
- Projection of post retrofit conditions.
- This results in need to use statistical regression techniques and makes the M&V complex and leads to expensive M&V costs.

7 of 15

M & V Issues

(Industries - continued)

- M&V becoming complex when Energy Conservation Measures (ECM) for a central utility equipment in a multi-product facility is envisaged.
- Need for altering M&V procedures due to changes in top management / key personnel.

8 of 15

M &V Issues

(Industries - continued)

- Expensive M&V costs towards calibration of meters, M&V efforts.
- Inability to appreciate benefits of M&V such as sustained savings- as it costs additional.

9 of 15

M&V Issues

(commercial)

- Difficulties in the definition of system boundary line.
- Absence of separate distribution & /or meters for lighting & other loads.

10 of 15

M&V Issues

(commercial contd.)

- Absence of standard M&V procedures leading to disagreement on establishing base line.
- Shift in baseline due to expansion/ modernization .
- Preferring whole billing analysis and a simple M&V procedure.

M&V Issues

(residential)

- Metering common area benefits and apportioning benefits in apartments.
- Baseline determination issues due to variations in occupants & usage pattern for domestic solar water heating, lighting etc.

Funding issues

- M&V can be used as a tool for defining and controlling risks.
- A standard M&V protocol shall provide credence to financing ESCO projects giving greater confidence to financial institutions (as risks are mitigated).

13 of 15

Need for M&V Protocol

- Tremendous ESCO opportunities.
- Concept new relatively & therefore long selling cycle.
- In the absence of standard M&V procedures and desire to shorten this cycle, ESCOs try to close deals with simple M&V.

14 of 15

Development of India specific M&V protocol

- IPMVP(International Performance measurement and verification Protocol) and FEMP(Federal Energy Management Program) have been reviewed for their suitability and applicability in Indian scenario to bring out India specific M&V protocol

15 of 15

Measurement & Verification

An Overview

Mark Stetz
Schiller Associates

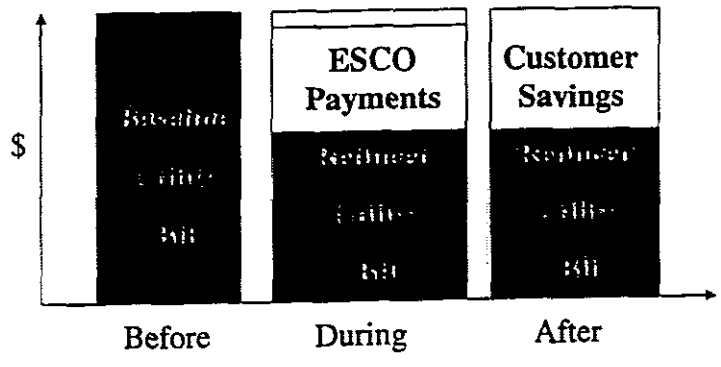
Outline

- Performance Contracting
- Financing
- M&V from Contracting Perspective
- M&V to Mitigate Risk
- Types of Risk
- How M&V Mitigates Risk and at What Cost

Performance Contracting

- Provides energy and $ savings to customer
- Actual savings are uncertain
- ESCO paid from savings
- Savings are often guaranteed
- How do we enforce guarantees?

PC Financing



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What is M&V? Contracting Perspective

- Tool for defining and controlling risk
- Risk mitigation (*risk = need to verify*)
  - Value of project
  - Uncertainty about savings
- Risk allocation between the parties:
  - Who is responsible for performance?
  - Who is responsible for achieving long-term savings?

M&V Mitigates Risk

- M&V serves as project insurance by demonstrating that savings are real.

Buy what you need,
get what you pay for.

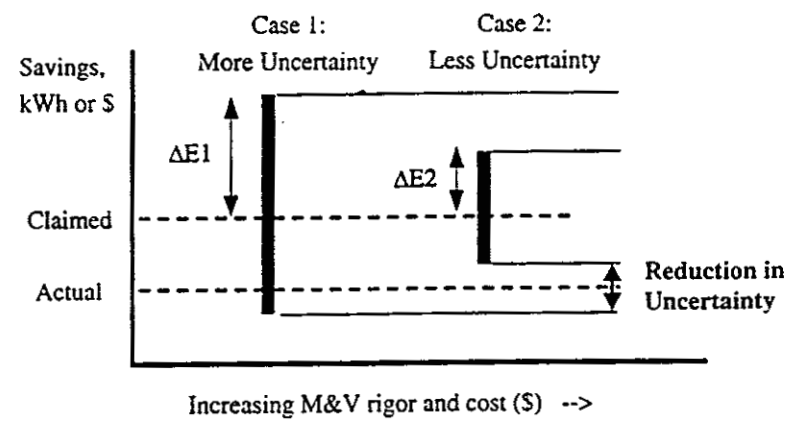
Types of Risk

- Uncertainty Risk (Measurement)
- Performance Risk (Equipment)
- Usage Risk (Hours, occupancy...)
- Financial (interest rates, energy costs...)

Uncertainty Risk

- Claimed savings are always estimates because *savings cannot be measured.*
- Uncertainty is introduced through:
  - Measurement error
  - Sampling error
  - Random variations
  - Simplifying assumptions
- *These are factors inherent in M&V*

Uncertainty Risk



Performance Risk

- Performance of an ECM may change over time due to equipment degradation and/or poor O&M practices. Performance may also be compromised by poor design or implementation.
- *These are factors that the ESCO normally controls.*

Performance Risks

	Customer	ESCO
Equipment Performance	-	X
Maintenance	x	x
Operation	x	x

Usage Risk

- Savings are dependent on both performance and usage. Usage can be defined as:
  - operating hours (lighting, equipment)
  - occupancy or schedules
  - heating load (& setpoint)
  - cooling load (& setpoint)
- *These are factors that the customer controls*

Usage Risk

	Customer	ESCO
Operating Hours	X	
Loads (occupancy, production...)	X	
Weather		
Equipment Life	x	X
User Participation	X	

Financial Risk

- Financial factors (such as interest rates and energy costs) affect cost and savings, but many are functions of market conditions. Typically, the effect of these unpredictable factors needs to be decided in advance.
- *These are factors that the market controls.*

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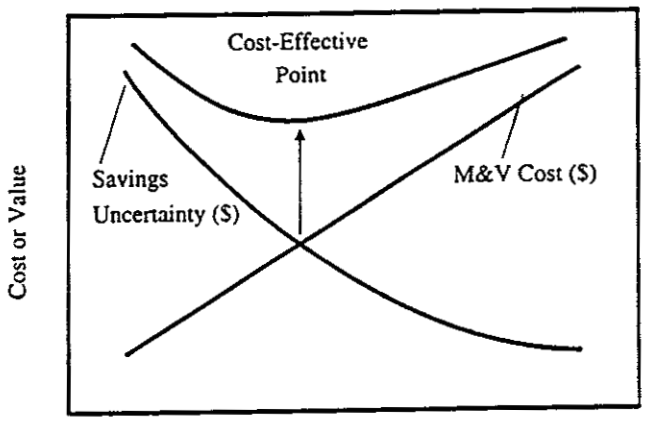
Financial Risk

	Customer	ESCO
Energy Prices		
Interest Rates		
M&V Costs	X	X
Construction Costs		X

Cost vs. Uncertainty



Measurement & Verification Resources and Training Opportunities

Prepared by

1333 Broadway, Suite 1015
Oakland, California 94612
510.444.6500
www.schiller.com

June 9, 2000

for

U.S. Department of Energy's Federal Energy Management Program (FEMP)

Measurement & Verification Resources and Training Opportunities

Measurement and Verification Resources and Training Opportunities

Measurement and verification (M&V) of energy savings, generated through building systems retrofits and upgrades, requires special project planning as well as unique engineering practices. Although several common practices exist for M&V of energy savings, it is not an exact science. There are many resources available that can be used to learn more about the engineering techniques and tools used for verification of energy savings. This document lists some of those resources. It is not intended to be a comprehensive listing of resources, but rather indicative of the types of tools that are available.

Table 1: Overview of M&V Tools

Report Section	Includes	Purpose in M&V
M&V Guidelines	❖ FEMP IPMVP ASHRAE 14P	Provide M&V standards based on accepted, proven strategies.
Utility & State Program M&V Guidelines	❖ California SPC Central Power & Light NYSERDA Texas Loan Star Program	Provide M&V standards based on accepted, proven strategies, which may be simplified and specified for certain applications.
Case Studies	California SPC Program FEMP	Example applications of M&V strategies.
Software & Hardware Tools	❖ Building energy simulation software System performance simulation software Utility cost management software Software and hardware tools for data acquisition and management	Available tools that can be used to: model building and systems to estimate savings; track utility costs to verify savings; measure equipment operations; measure and recording of variable operating parameters; process recorded data.
Other Resources	Commissioning guidelines Related papers	Other resources that could be utilized when preparing for and implementing the measurement and verification of energy savings.

1 M&V GUIDELINES

Several guidelines have been published on measurement and verification energy savings. Each of the Guidelines listed in this section are unique, albeit similar, and are intended for use in different instances. All of these documents provide standard M&V methods that are proven and accepted strategies.

1.1 FEMP M&V Guidelines Version 2.0

The Federal Measurement and Verification (M&V) Guideline provides procedures and guidelines for quantifying the savings resulting from the installation of energy conservation measures. Intended for use in Energy Savings Performance Contracting (ESPC) and utility program projects, the guideline provides the methodology for establishing energy cost savings called for in the ESPC rule. These guidelines are available at www.eande.lbl.gov/CBS/femp/MVdoc.html.

1.2 International Performance Measurement and Verification Protocol

The International Performance Measurement and Verification Protocol (IPMVP) is a document which discusses procedures that, when implemented, allow building owners, energy service companies, and financiers of buildings energy efficiency projects to quantify energy conservation measure (ECM) performance and energy savings. The IPMVP provides an overview of current best practice techniques available for verifying savings from both traditionally- and third-party-financed energy and water efficiency projects. These guidelines are available at www.ipmvp.org/.

1.3 ASHRAE PROPOSED GUIDELINE 14P

The ASHRAE guideline is called *Measurement of Energy and Demand Savings*, Advanced Working Draft #1, December 13, 1999 © ASHRAE. The proposed requirements in this draft are subject to change before final approval by ASHRAE.

ASHRAE Guideline 14P was developed by ASHRAE to provide guidance on the minimum acceptable level of performance in the measurement of energy and demand savings for the purpose of a commercial transaction based on that measurement.

ASHRAE Guideline 14P deals only with the measurement of energy and demand savings. Other tasks are needed in any energy performance contract. Review copy is available at http://www.ashrae.org/standards/availdft.htm.

2 M&V GUIDELINES FROM CURRENT UTILITY & STATE PROGRAMS

Many electric and gas providers in the U.S. offer incentive payments for verified energy savings. Each of these incentive programs has guidelines specifying their individual requirements for the measurement and verification of energy savings. This list of programs is not comprehensive, but includes programs that have M&V guidelines that are easily accessible.

2.1 California Utility SPC Program

This statewide energy-efficiency program is being offered by San Diego Gas & Electric, Pacific Gas and Electric Company and Southern California Edison (Utility Administrators) under the direction of the California Public Utilities Commission (CPUC). The Large Non-Residential Standard Performance Contract (LNSPC) Program is a performance-based program that offers incentive payments to Projects Sponsors who develop projects delivering verified energy savings at Host Customer facilities. This program offers fixed incentive prices to Project Sponsors for verified and documented energy savings achieved by the installation of specific, energy-efficiency measures. Energy savings will be measured and verified annually by the Project Sponsor over a two-year period following the approval and installation of the energy-efficiency equipment. Additional information about the individual utility programs can be found at www.pge.com/spc/large_nr/measurement.html, www.scespc.com/nonresidential.htm, and http://www.sdge.com/business/.

2.2 Central Power and Light

Central Power and Light in Texas is planning to introduce a new program for commercial and industrial facilities. This program is called the Non-Residential Standard Performance Contract (SPC) Pilot Program. SPC Program Manual, including M&V Guidelines, can be found at www.csw.com/About_CSW/default.htm.

2.3 NYSERDA

The New York State Energy Research and Development Authority offers the Energy $mart^{SM} Standard Performance Contract (SPC) program. This program offers fixed-price incentives to energy service companies (ESCOs) that install cost-effective electric energy efficiency measures. Project-specific incentives will be calculated based on a per-kWh-of-annual-savings basis and paid out 40% upon installation and the balance over a two-year measured performance period as specified in an SPC Agreement. The M&V Guidelines for this program, along with sample M&V plans can be found at www.nyserda.org/499pon.html.

2.4 Texas Utilities

Information on TXU Electric's Energy Efficiency Markets (TEEM) programs can be found at http://www.txuefficiency.com/. TXU Electric's two energy efficiency pilot programs are: the Small Air-Conditioner Program and the Commercial and Industrial Retrofit Program, which includes measurement and verification requirements.

2.5 Texas Loan Star Program

This program, which includes measurement and verification of savings, is used for Texas State Agency energy projects. *Overview of the Texas LoanSTAR Monitoring Program* was published in the *7th Annual Symposium on Improving Building Systems in Hot and Humid Climates 1990,* October 9-10, 1990, Fort Worth, Texas. The document and details about the program are available at www-esl.tamu.edu/loanstar/about_LoanSTAR.html.

Texas LoanSTAR Monitoring Workbook is intended to be a stand-alone survival guide to acquiring energy use and environmental data in buildings. It includes monitoring procedures and data analysis routines developed for the Texas LoanSTAR program and is available for $38.00

3 CASE STUDIES

One of the best ways to understand measurement and verification of energy savings is to learn from examples. Several sources of case studies and related materials are listed below.

3.1 California SPC Program Case Studies

Several example M&V Plans are included in Appendix D of the California Utility SPC Program M&V Guidelines. Included in this document are M&V Plan Template, VSD Installation M&V Plan, Constant Speed Chiller Replacement M&V Plan, Variable Speed Chiller Replacement M&V Plan, and Calibrated Simulation M&V Plan. It is available at www.pge.com/spc/large_nr/forms.html.

3.2 FEMP Case Studies

Demonstrations projects provide first-hand details on some of the latest federal projects at www.eren.doe.gov/femp/prodtech/successstories.html.

- **The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, Louisiana**

Final Report, Report ORNL/CON 460 (1998), by P.J. Hughes and J.A. Shonder, Chapter 7 "Measurement and Verification of Energy Savings"

Additional information is available at http://www.eren.doe.gov/femp/financing/ghpresources.html#savings.

4 TRAINING OPPORTUNITIES

Several organizations offer classes on measurement and verification of energy savings. Some upcoming courses are listed below.

4.1 AEE M&V Courses

The Association of Energy Engineers offers a course on measurement and verification of energy savings.

- **Management, Measurement & Verification For Performance Contracts**

November 30 - December 1, 2000, Buena Vista Suites, Orlando, FL, (800) 537-7737

With use of performance contracting to finance energy projects continuing to grow, it is important to be able to quantitatively assess results and project and measure payback. At this informative seminar, you will learn the skill and art of managing and monitoring a performance contract, to assure that you are getting the results you expect. You'll hear case studies illustrating how and why certain projects have "gone bad," and what steps you can take to avoid potential pitfalls. You'll also hear analysis of successful projects, and the factors contributing to their success. You'll leave the course with the tools you need to track your project along the way using M&V methods developed by leading experts with broad, hands-on experience in managing performance contracts. Regular Fee: $945, AEE Member Fee: $845*, Government & Nonprofit Fee: $845. Additional information is available at www.aeecenter.org/seminars/.

4.2 ASHRAE M&V Courses

The American Society of Heating Refrigeration and Air-conditioning Engineers offers a course on measurement and verification of energy savings.

- ***Determining Energy Savings From Performance Contracting* Projects – Measurement And Verification**

October 3, 2000—San Jose, CA. This course provides an overview of measurement and verification (M&V) procedures and methods for determining savings from energy efficiency projects. Four brief case studies will be presented to illustrate concepts and issues associated with M&V: a lighting project (using both estimates and long-term metering), a VSD project (using long-term metering), a billing analysis and a calibrated simulation. Additional information is available at www.ashrae.org/.

4.3 FEMP Courses

The federal energy management Program offers courses related to various aspects of performance contracting. A complete listing of courses is available at http://www.eren.doe.gov/femp/resources/training/femptraining.html.

- **Water Resource Management**

How to assess, evaluate, resolve, and incorporate water efficiency into Federal project-assessment, planning and implementation programs. Additional information is available at www.eren.doe.gov/femp/resources/training/fy2000water.html.

- **Energy 2000**

August 21-23 Energy 2000 - Pittsburgh, PA

FEMP Symposia regarding all aspects of performance contracting, including measurement and verification of energy savings. Additional information is available at www.eren.doe.gov/femp/resources/training/femptraining.html.

5 TOOLS FOR DATA COLLECTION AND ANALYSIS: SOFTWARE & HARDWARE

Several types of software and hardware related to energy analysis are available. Some software is available at no cost, while other programs can be purchased. This is not intended to be a comprehensive list of all programs that are available nor a recommendation for any particular tool, but rather an indicator of the types of existing tools. The software is categorized as either: Building Energy Simulation, System Performance Simulation, Utility Cost Management, or Data Acquisition and Management. Information on additional energy software tools can be found at www.eren.doe.gov/buildings/tools_directory/ and eande.lbl.gov/CBS/eXroads/soft.html.

5.1 Building Energy Simulation Software

- **BLAST**

BLAST (Building Loads Analysis and System Thermodynamics) performs hourly simulations of buildings, air handling systems, and central plant equipment in order to provide mechanical, energy and architectural engineers with accurate estimates of a building's energy needs. The zone models are based on the fundamental heat balance method, are the industry standard for heating and cooling load calculations. BLAST output may be utilized in conjunction with the LCCID (Life Cycle Cost in Design) program to perform an economic analysis of the building/system/plant design.

Available through Building Systems Laboratory, University of Illinois, 1206 West Green Street, Urbana, Illinois 61801, telephone (217) 333-3977, facsimile (217) 244-6534 or www.bso.uiuc.edu. Software prices range from $450 for an upgrade package to $1500 for new installations.

- **DOE-2**

Performs hourly simulation of new and existing buildings based on the building's climate, architecture, materials, operating schedules, and HVAC equipment. Appropriate for use with Option D.

Available through LBNL, Buildings Technology Program, Kathy Ellington, fax: (510) 486-4089 or http://gundog.lbl.gov/.

- **VisualDOE2.5**

VisualDOE is a graphical version of DOE2. Users can model complex buildings and HVAC systems. Provides results in graphical format. Software is available from Eley Associates, 142 Minna Street, San Francisco, California 94105. Phone: 415-957-1977, fax: 415-957-1381, email: info@eley.com. http://www.eley.com/.

- **Energy-10**

Energy-10 is a simple graphical building simulation program for evaluating buildings while still in the design stage. Good for residences and small offices. Can be used to evaluate different potential energy-efficiency measures including passive solar. Available through the Sustainable Buildings Industries Council (SBIC), 1331 H Street, N.W., Suite 1000, Washington, DC 20005, Phone: (202) 628-7400, fax: (202) 393-5043, email: sbic@sbicouncil.org, http://www.sbicouncil.org/

5.2 System Performance Simulation Software

- **CoolTool**

Software offers component level modeling of chiller plant, simulating performance of electric chillers & cooling towers. Provides hourly energy cost analyses of chiller water plant equipment and control alternatives. Appropriate for use with Option D. Electric chiller model is now in beta release.

Available through Pacific Energy Center, Mark Hydeman, 851 Howard Street, San Francisco, CA 94103, tel: (415) 972-5498, fax: (415) 1290, www.hvacexchange.com/cooltools.

- **QuickChill**

Designed to evaluate performance changes when converting from R-11or R-12 to another refrigerant. Can also be used to evaluate chiller staging strategies and condenser & evaporator water temperature reset. Software was developed by the US Environmental Protection Agency and is available at http://www.epa.gov/buildings/esbhome/tools/software.html.

- **Market Manager**

Simulation software using standard ASHRAE algorithms that allow modeling of building systems, sub-systems, and components. Appropriate for use with IPMVP/FEMP Options C and D.

Available through SRC SYSTEMS, INC., 2855 Telegraph Ave., Suite 410, Berkeley, CA 94705, tel: (510) 848-8400, fax: (510) 848-0788, www.src-systems.com.

5.3 Utility Cost Management Tools

- **Energy Accounting: A Key Tool in Managing Energy Costs**

Energy accounting is a system to record, analyze and report energy consumption and cost on a regular basis. This downloadable guide will discuss some of the reasons for energy accounting, go into background information needed to understand it, and explain how to get started with a program. With emphasis on computer software, this document will discuss some of the methods and means of energy accounting, focusing in on energy accounting software packages. The

appendix reviews and provides information on five of the most popular, commercially available energy accounting software packages. It is available at www.energy.ca.gov/reports/efficiency_handbooks/index.html.

- **FASER 2000**

Tracks, analyses, and reports utility billing data, as a result detects billing and metering errors, identifies electrical and mechanical problems, and highlights cost saving opportunities. Appropriate for use with IPMVP/FEMP Option C.

Available through OmniComp, Inc., 220 Regent Court, State College, PA 16801, tel: 1-800-726-4181, fax: (814) 238-4673, www.faser.com.

- **METRIX**

METRIX is software designed to track utility usage and costs in order to track operating cost savings or verify the impacts of utility performance measures. Metrix creates a historical baseline using a multi-variant linear regression to correct for weather and other independent variables that affect utility cost. It establishes performance targets and can track an unlimited number of sites, facilities, and meters. Appropriate for use with IPMVP/FEMP Option C.

Software prices range from $2,495 to $4,495 depending on the type of license purchased. See web site to download an evaluation version. Available through SRC Systems Inc., Suite 410, 2855 Telegraph Avenue, Berkeley, California 94705, telephone (510) 848-8400, facsimile (510) 848-0788 or www.src-systems.com.

5.4 Tools for Data Aquisition and Management

- **Abacus**

Provides wireless meter information that can be used to detect abnormal energy use and assess the impact of measures immediately. Use could include monitoring for IMPVP/FEMP Options B and C.

Available through Ameren (abacus.amerren.com).

- **ARC Systems**

Complete line of compact Information Loggers Small data loggers record temperature, relative humidity, electric current, pressure and other standard variables without plugs, power supplies, signal conditioning or complex in-field setups. Equipment can be used for monitoring for IPMVP/FEMP Option A, B, and D.

Information is available at www.acrsystems.com/menu.htm.

- **ACRx™**

ACRx acquires and processes technical data (air temperatures, refrigerant temperatures and pressures, etc.) to identify pending service needs, can be used for monitoring for Option A, B, and D.

Available through Field Diagnostic Services, Inc., North American Technology Center, 680 Jacksonville Road, Warminster, PA 18974, Tel: (215) 672 9600, Fax: (215) 672 9560, www.acrx.com.

- **Analysis West**

Analysis West is a manufacturer and distributor of energy monitoring and software products for energy and HVAC professionals. Runtime DataWatcher datalogger records the runtime of fuel-fired heating systems, including hard-to-measure water heaters and millivolt heating systems. A separate sensor allows the unit to also log motors, air conditioners and other electrical appliances. Up to 11 months of data can be stored in the logger. Digital Power Meters allow you to measure the true power consumed (Watts) by plug-in electrical appliances and lights. Total kilowatt-hours used over an extended monitoring period are also recorded.

Information is available at www.energytools.com/.

- **Architectural Energy Corporation**

Architectural Energy Corporation's (AEC) MicroDataLogger® portable data acquisition system is a battery or line-powered, four-channel data logger and hand-held meter which records time-series data from virtually any sensor or transducer, including temperature, relative humidity, pressure,

electrical current, power, air flow, velocity or lighting levels. Made for use with Enforma™ software, which allows visualization and analyses of short-term data taken from portable loggers. Collect and analyze system-wide HVAC, controls and lighting performance data over time. Detect HVAC problems, determine energy use baselines, and verify savings of lighting retrofits, commission or re-commission building HVAC, control, and lighting systems. Use could include monitoring for IMPVP/FEMP Option A, B, and D. Available through Architectural Energy Corporation, 2540 Frontier Ave., Suite 201, Boulder, CO 80301, tel: (303) 444-4149, fax: (303) 444-4304, www.archenergy.com.

- **Boonton Test Solutions**

Products include test instruments & sensors, including power meters. Appropriate for short-term measurements associated with IPMVP/FEMP Options A & B.

Information is available at www.boonton.com/.

- **CellNet Online Meter Reader**

Real-time energy use tracking to detect abnormal energy use and assess the impact of measures immediately after installation. Use could include monitoring for Options B and C.

Available through CellNet Data Systems, 125 Shoreway Road, San Carlos, CA, www.myEnergyInfo.com.

- **Continental Control Systems**

Continental designs and manufactures AC power and energy meters. Available products include standard pulse-output watt-hour transducers and LonWorks interoperable power, energy, and demand meters. Applications include utility sub-metering, end-use metering, equipment performance monitoring, verification, evaluation, and diagnostics.

Information is available at www.ccontrolsys.com/.

- **E-MON Corporation**

Solid state electric meters and meter reading systems and software. E-MON D-MON electric meters install easily to meter KWH and/or demand of electricity. E-MON CE-MON systems and software can be installed on either E-MON meters or any manufacturer's meters for automatic meter reading and profiling. Information is available at www.emon.com/.

- **Fluke Corporation**

Manufactures, distributes and services electronic test tools.
Information is available at www.fluke.com/.

- **Highland Technology**

Precision Electronic Instrumentation including energy measurement products.
Information is available at www.highlandtechnology.com/.

- **Measuring and Monitioring Services**

Services include end-use metering, load research, energy monitoring and analysis, water system monitoring as well as related hardware and software products.
Information is available at www.mmsinc.com/.

- **MeterTeck Inc.**

Data collection and management, including services, hardware, and software.
Information is available at www.metretek.com/.

- **Onset Computer Corp.**

Onset offers over 70 models of miniature data loggers and logger/controller engines. The popular HOBO & StowAway loggers, paired with BoxCar Pro software for Windows, allow you to quickly and easily record temperature, relative humidity, light intensity, lighting run time, rainfall, AC current, DC voltage, motor on/off, light on/off, open/closed states and events.
Available through Onset Computer Corporation, 536 MacArthur Blvd., Pocasset, MA 02559-3450, tel: (508) 563-9000, fax: (508) 563-9477, www.onsetcomp.com.

- **Pacific Science & Technology Inc.**

A variety of energy monitoring products, including tools designed to record the time-of-use and run-time of devices, current, temperature, and pulse counts, true RMS 3-phase recording power meter.
SmartLog is data analysis software for use with PS&T loggers. Tool provides graphs and results of the data. Tool can convert data to text format for further analysis with spreadsheet, etc. Works with PS&T loggers only. Use could include monitoring for IPMVP/FEMP Option A, B, and D. Available through Pacific Science and Technology, Inc., 64 NW Franklin Ave., Bend, OR 97701, tel: (541) 388-4774, fax: (541) 385-9333, web www.pacscitech.com/.

- **PowerFocus**

Forecasting of energy use by load using predicted models. Use could include assisting with building monitoring for Options B and C - analysis of utility bills, refrigeration and HVAC energy usage.
Available through Power Control Technologies, Tel: (410) 403-4000 www.powerfocus.com.

- **PSI Flow Instruments**

Process control and instrumentation, including a wide range of flow meters.
Information is available at www.psi-kc.com/html/products/flow.html.

- **Texas A&M**

Various software programs designed to help users manipulate and analyze energy consumption data are available through Texas A&M at www-esl.tamu.edu/software/software.html

- **TimeFrame**

TimeFrame offers a database for data collection of lighting and motor projects. Consists of sensors (current or voltage types) that are hardwired at the site and remote computer for data collection and storage and analysis. Data retrieval is remote via modem. Use could include monitoring for Option A, B, and D.

Available through Measuring and Monitoring Service Inc., 620 Shrewsbury Ave., Tinton Falls, NJ 07701, tel: (800) 942-2703, fax: (732) 576-8067, www.mmsinc.com.

- **Veris Technology**

Veris offers a variety of energy automation sensors including power meters, remote energy reporting tools, and metering software.

Information is available at www.veris.com/.

- **Vistron**

Vistron offers products for energy measurement and remote meter reading. Products include run time meters for any intermittently operated electric device and a remote register of a utility meter.

Information is available at www.vistron.com/.

6 OTHER RESOURCES

There are many additional resources that could be utilized when preparing for and implementing measurement and verification of energy savings. Some of these resources are included here.

6.1 ASHRAE Guideline 1 on Commissioning

Guideline 1-1996 - The HVAC Commissioning Process describes the commissioning process that will ensure heating, ventilating and air-conditioning (HVAC) systems perform in conformity with design intent. Document is available through www.ashrae.org/ for $32.00.

6.2 DOE Building Commissioning Guide: Version 2.2 (Draft)

DOE's Federal Energy Management Program (FEMP), in cooperation with the General Services Administration, developed the Building Commissioning Guide. This Guide was originally released for comment on June 16, 1997. Since that release date, comments have been received and incorporated into the Draft Building Commissioning Guide: Version 2.2. The Guideline is available at www.eren.doe.gov/femp/techassist/bldgcomgd.html.

6.3 NEBB Procedural Standards for Building Systems Commissioning

This publication contains uniform and systematic procedures for the commissioning of building systems developed by national and international NEBB commissioning firms. In addition to the general procedures, there are specific procedures for HVAC systems, sample forms, checklists, and a 23-page glossary of building systems and engineering terms in a loose-leaf binder with tabs. Publisher: NEBB; Pub year: 1993. Document is available through www.ashrae.org/ for $52.00.

6.4 Predicting and Verifying Energy Savings for Energy Service Companies Using Short-Term Monitoring 3.25

This study by W.Mark Arney, Stuart S. Waterbury, Matthew J. Ossi was published in 1998 ACEEE *Summer Study On Energy Efficiency In Buildings Proceedings.* It can be ordered through www.aceee.org/pubs/pan398.htm.

6.5 The Energy Efficient Project Manual

This book is published by national Association of Energy Services Companies (NAESCO) and the Department of Energy fro the Energy Fitness Program. It is sub-titled *The Customer's Handbook To Energy Efficient Retrofits: Upgrading Equipment while Reducing Energy Consumption And Operating And Maintenance Costs.* This overview of performance contracting has a chapter on measurement and verification, and can be downloaded from http://www.ornl.gov/EFP/efp.htm.

I. What Is Measurement and Verification?

What is M&V? Contracting Perspective

- Tool for defining and controlling risk
- Risk mitigation *(risk = need to verify)*
  - Value of project
  - Uncertainty about savings
- Risk allocation between the parties:
  - Which party is responsible for EEM performance?
  - Which party is responsible for achieving long-term savings?

What is M&V? Engineering Perspective

- ***Measure*** energy use before and after installation of EEMs
- ***Verify*** that EEMs continue to perform and generate savings
- ***Quantify*** energy savings by comparing before and after energy use

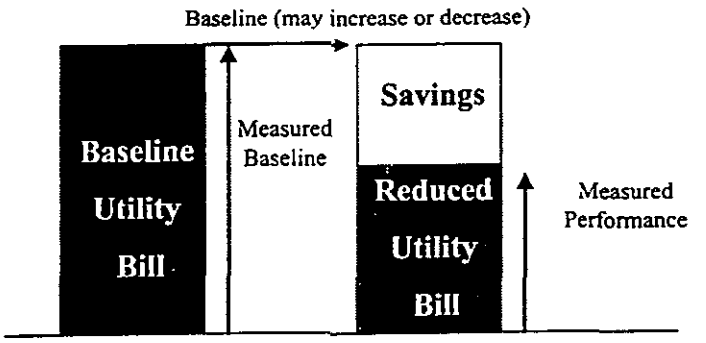
Uses of M&V

- Determine energy savings
- Integrated with commissioning can provide feedback on performance of EEMs
- Long-term feedback for ongoing fine-tuning of EEMs
- Documentation for evaluating (and justifying) future EEMs
- Research

FEMP M&V Guideline

- Manual for federal energy projects
- Step-by-step procedural guide
- Defines M&V methods
- Next update 8/2000 (Ver 2.2)

M&V Terminology



Savings Cannot Be Measured!

- Savings are determined by comparing:
  - Post-retrofit energy against
  - Baseline energy use
- The baseline may need to be adjusted,

Two Components To Measurement and Verification

- Verify potential to generate savings
- Determine savings

Performance

Example: Tune-up

Potential to Generate Savings:

Before	->>	Tune-Up	->>	After
25 mpg				50mpg

Savings:
Savings determined by miles driven per year

Good M&V Design Requires

- Deciding how both potential and actual savings will be determined
- Deciding how to balance:
  - Accuracy and repeatability (rigor) of the M&V
  - The cost of the M&V

Identify Goals and Objectives

- Define the M&V goals
- Define the value of the project and the value of the M&V goal - **how accurate of a result is needed**
  - Do not spend $10,000 to estimate the savings on a $20,000 project

Identify Goals and Objectives (cont.)

- Define resources available in terms of time, money, people, etc.
  - A complex but incomplete M&V effort is rarely better than a simple but completed effort.

M&V Implementation Procedures

M&V activities can be divided into the following tasks:

- Define a general M&V approach
- Define a *site-specific plan* for the particular project
- Define pre-installation baseline
- Define post-installation situation/energy use
- Calculate energy savings for the first year
  - For a performance contract, calculate first-year payments
- Conduct annual M&V activities
  - For a performance contact calculate annual payments

Requirements for a Project-Specific M&V Plan

- State which option and method will be used
- Indicate who will conduct the M&V
- Define the details of how calculations will be made
- Specify the metering (points, period, analyses and metering protocols)
- Define key assumptions
- Define the level of accuracy
- Define how baseline adjustments will be made
- Define how quality of service will be verified
- Define any sampling that will be used (accuracy)
- Define quality assurance methods
- Define reporting contents and schedule

M&V Issues

- Defining the baseline and keeping it up to date
- Accuracy and uncertainty
- Selecting the variables to meter and monitor
- Data logging options
- Length of metering/monitoring period
- Energy costs
- How much M&V is enough
- Costs of M&V
- Sample sizes

Defining the Baseline

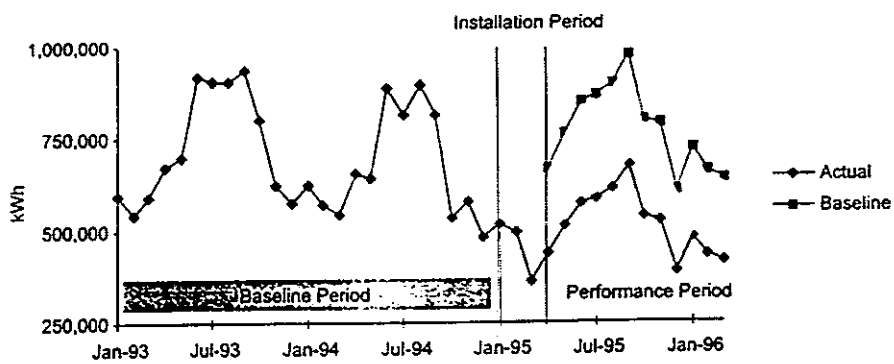
- Are existing conditions at facility stable?
  - Operating conditions (e.g., occupancy)
  - Maintenance
- Is the load variable or constant?
- Can variables affecting load be identified?
- How long does the baseline have to be measured?
- What is the term of the contract?

Adjusting the Baseline

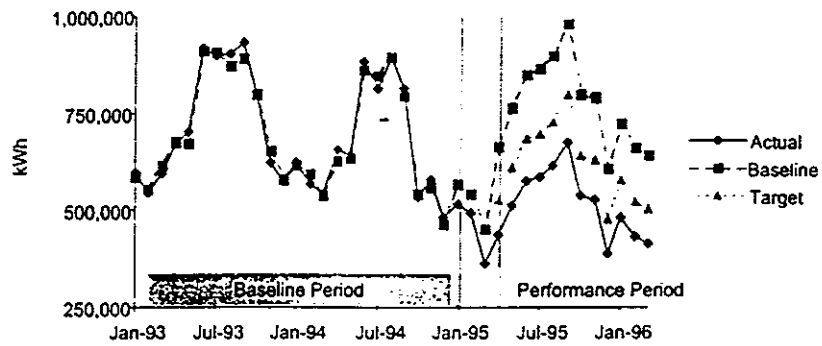
- Most baselines are not really constant and thus the baseline is usually defined as a model
- Define (before the fact) what influences the baseline and when will it be modified, e.g.:
  - Typical vs. actual weather
  - Typical vs. actual occupancy
- Define how baseline will be adjusted, if at all

What You Think Will Happen

The next few slides are from: Robert Sondregger, SRC Systems Inc.



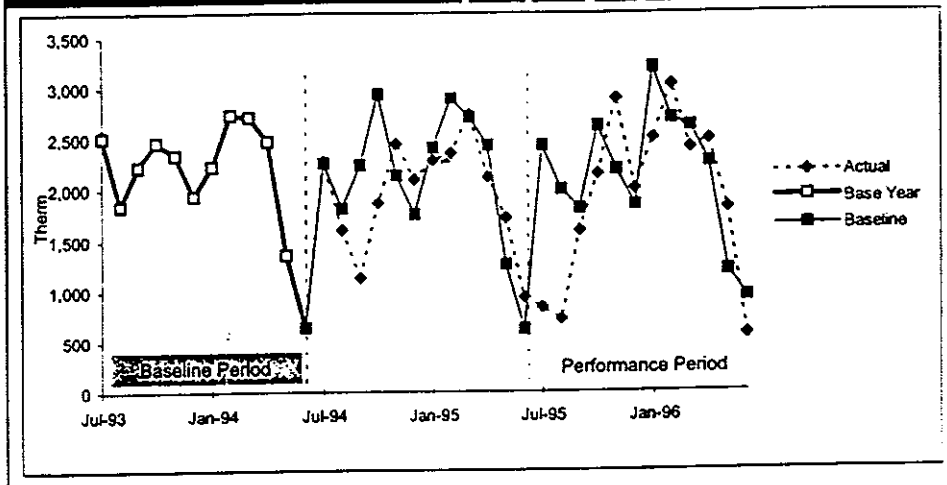
What You Want to Happen



What Can (And Will) Happen

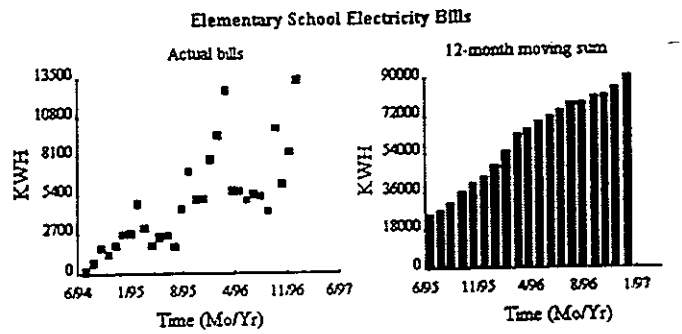
- Facility usage changes
- Facility equipment changes
- Facility undergoes construction
- Projected savings do not materialize

What Really Happens



Plug Creep

- M&V challenge -- moving target!
- Significant upward trend



Verifying the EEM's Potential to Generate Savings

- Were baseline conditions accurately defined? (Were proper equipment/systems installed?)
- Are the systems performing to specification? (Do systems have potential to generate predicted savings?)
- Is there continuing potential for savings?

Baseline and Post-Installation Conditions Are Verified Using

- Inspections
- Spot measurement tests
- Commissioning activities

Savings Are Determined Using

- Agreed-upon stipulations
- Engineering calculations
- Metering and monitoring
- Utility meter billing analysis
- Computer simulations (example: DOE-2 analysis)

Rate Schedules

- Different fuels
- Block structure (e.g., $0.09/kWh for the first 1000 kWh, $0.05/kWh for next 1000 kWh, etc.)
- Different tariffs by time-of-use
- Demand charges
- Billing demand ≠ Metered demand!
- Ratchets, billing credits, misc. charges...

Energy Costs

- Define rate structure and how it is calculated
- Determine what factors are required to calculate bill and thus what must be metered (and at what intervals) (example: motor soft start)
- Account for changes in rates (or rate schedules) in presenting results

Four M&V Options

- Four M&V options defined in the 2000 FEMP Guidelines.
- No option is necessarily better or more/less expensive than another
- Each M&V option is applicable to different situations

Definitions

- **Options:** One of four M&V approaches defined in FEMP & the IPMVP
- **Methods:** Generic, not project specific, M&V approach applied to a specific EEM technology
- **Techniques:** An evaluation tool for determining energy and cost savings (example: utility billing analysis)

FEMP Options

Option	Strategy	How Used	Benefits
A	Emphasis on stipulated values to minimize effort. Uses simple (if any) measurements to establish savings.	Component-level	Simple, low-cost
B	Relies on continuous monitoring to track performance of new equipment.		Reliable, tracks long-term performance.
C	Compares utility-bill consumption of entire facility.	Building or facility level	Tracks long-term performance, applicable to complex and multiple projects.
D	Uses computer simulation or regression modeling to estimate performance.		

Option A

- Projects where verifying the potential to generate savings is the major concern (or the risk to be mitigated)
- Actual energy or cost savings are not verified; they are predicted using engineering or statistical methods that may involve spot or short-term, but not long-term measurements
- Option A includes primarily verification activities and updating/improving estimates used in a feasibility study

Option B

- Projects where actual savings during contract need to be determined
- Involves long-term measurements
- Savings are determined by end-use
- A Retrofit Isolation method
- **Same procedures as Option A** plus measurement of pre- and post-installation energy use

Option C

- Projects where actual savings during the contract need to be determined
- Utility whole-facility meter analysis
- Savings are determined by **whole facility**
- **Same procedures as Option A** plus measuring actual energy use during the term of the contract

Option D

- Use of a calibrated simulation tool to estimate before and/or after energy use
- Simulation for a whole building or just an end-use
- Building simulation model (e.g., DOE-2), or a spreadsheet, or VSD estimating program, etc.
- Calibration is done by:
  - Linking simulation inputs to actual operating data, and
  - Comparing the simulation results with end-use or whole building data

Comparing Options

- Option A: Verifying potential for acceptable savings
- Options B and C: Measuring actual post-installation energy use
  - Option B - by end-use
  - Option C - whole building
- Option D: Calibrated simulation - perhaps a hybrid of A and B or C

Example Lighting Project M&V Option A

- Baseline is 100 watt light bulb and new lamp is 25 watt compact fluorescent
- Wattage verified by "nameplate data"
- Assumed operating hours are 3,000/year:
  - Prior study
  - A week or two of monitoring
  - Estimate by owner, etc.
- Calculated savings are 3,000 x (100 - 25) = 225 kWh/year

Example Lighting Project M&V Option B

- Baseline is 100 watt light bulb and new lamp is 25 watt compact fluorescent
- Wattage verified by "nameplate data"
- **Measured** operating hours are 3,150 per year
- Calculated savings are 3,150 x (100 - 25) = 236.25 kWh/year

Example Lighting Project M&V Option C

- Baseline utility bill (adjusted for post-installation conditions) is 1,250 kWh/year
- Post-installation utility bill is 1,000 kWh/year
- Savings are 1,250 - 1,000 = 250 kWh/year

Example Lighting Project M&V Option D

- Input information on lights and HVAC system into simulation program
- Calibrate model with meter data
- Model predicts pre- and post-installation lighting and interactive HVAC energy use for determining savings

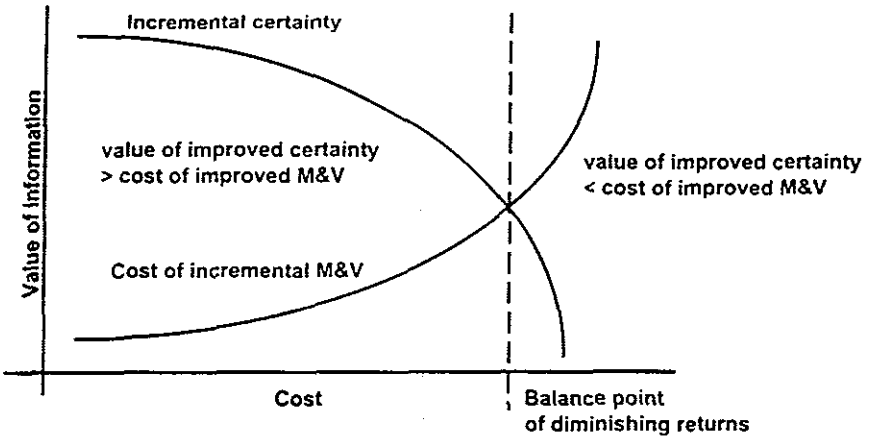
Accuracy and Uncertainty

- Sampling accuracy
- Measurement accuracy
- Human accuracy
- Repeatability

Selecting the Right Variables to Measure

- Many factors affect the savings from an EEM, but which will be measured or tracked determines accuracy, costs and frustration
- Define the factors; document why some are measured and some are not
- Consider tests and tracking of conditions that are not metered

How Much M&V Is Enough?



M&V Costs

- Option A: 1% - 5% of project costs
- Option B: 3% - 15% of project costs
- Option C: 1% - 10% of project costs
- Option D: 3% - 15% of project costs
- Using different levels of accuracy and risk avoidance can be the basis for differences in M&V costs, project pricing, and financing rates

Break and Time for Questions

Using Measurements

Lighting Measurements

- Lighting (Options A & B)
  - Usage Groups
  - Lighting Levels
  - Sample Sizes and Criteria
  - Operating Hours
  - Fixture Powers
  - Savings Calculations

Chiller Plant Measurements

- Chiller Plant (Option B)
  - Chiller Theory (water chiller)
  - Performance Curves
  - Monitoring: kW, tons, OSA, WB
  - Savings Calculations

Boiler Plant Measurements

- Boiler Plants (Options B & C)
  - Efficiency Measurements
  - Performance Curves
  - Savings Calculations (Option B)
  - Regression Modeling
  - Weather Adjustment
  - Savings Calculations (Option C)

Lighting: Usage Groups

- Need to define usage group by functional use to determine operating hours. Ex:
  - Office
  - Residential
  - Storeroom
  - Safety (24/7)
  - Exterior

Lighting: Levels

Lighting levels should be measured before and after retrofit.

Usage	Typical Levels
Data Processing	100 FC
Office	50 FC
Cafeteria	30 FC
Bulk Storage	10 FC
Parking Lot	1 FC

Lighting: Usage Groups

- Need to define precision and confidence criteria for each group
- Need to determine sample size
- Need to assess whether precision and confidence criteria were met.

Lighting: Usage Groups

- 20% precision at 80% confidence typical. (Z = 1.282, P = 0.2)
- Coefficient of variance assumed to be 0.5.

$$n = \frac{Z^2 \, C_{v,\,assumed}^2}{P^2}$$

$$C_v = \frac{std.\ dev.\ of\ hours}{average\ of\ hours} = 0.5\ (assumed)$$

$$n = \frac{(Nn)}{(N+n)}$$

$$n = \frac{(Nn)}{(N-n)}$$

$$P = \frac{Z \, C_{v,\,actual}}{\sqrt{n}}$$

Lighting: Sample Size ($C_v = 0.5$)

Precision	20%	20%	10%
Confidence	80%	90%	90%
Z-Statistic	1.282	1.645	1.645
Population Size, N	Sample Size, n*		
20	8	10	16
50	10	13	29
100	10	15	41
200	11	16	51
500	11	17	60
infinite	11	17	68

More precision requires more samples!

Lighting: Operating Hours

- Use run-time or TOU loggers for 2-4 weeks minimum to track usage.
- Measured usage determines annual hours for each usage group.
- Check measurement precision to see if it meets criteria.

Lighting: Fixture Power

- Measure fixture powers by type.
  - # of lamps and ballast
- Can measure multiple fixtures on one line.
- Can use VA measurements, true power preferred. (Ballasts have power factor)
- Power = V * A * Power Factor

Lighting: Typical Fixtures

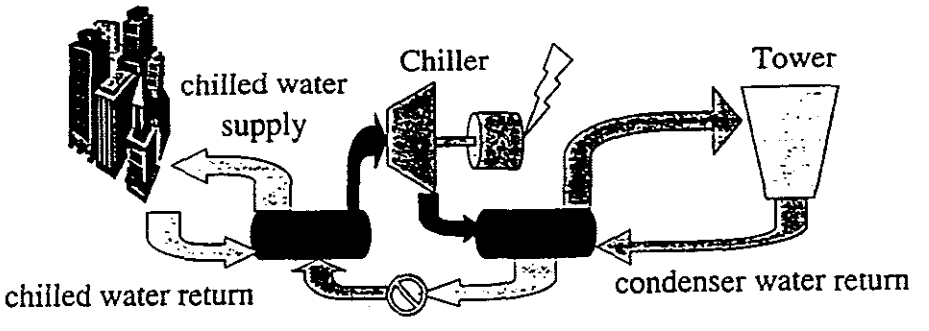
FIXTURE CODE	LAMP CODE	DESCRIPTION	BALLAST	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT
F42SE	F40T12	Fluorescent, (2) 48", STD lamp	Mag-ES	2	40	86
F42EE	F40T12/ES	Fluorescent, (2) 48", ES lamp	Mag-ES	2	34	72
F42LL	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	60
F43SE	F40T12	Fluorescent, (3) 48", STD lamp	Mag-ES	3	40	140
F43EE	F40T12/ES	Fluorescent, (3) 48", ES lamp	Mag-ES	3	34	115
F43LL	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	32	93
F44SE	F40T12	Fluorescent, (4) 48", STD lamp	Mag-ES	4	40	172
F44EE	F40T12/ES	Fluorescent, (4) 48", ES lamp	Mag-ES	4	34	144
F44LL	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	32	118

This is an excerpt from the Southern California Edison lighting table used for the Standard Performance Contracting DSM program.

Lighting: Savings Calculations

	Existing Lighting Equipment				New Lighting				Energy Use			
Usage Type	Fixture Code	# of Fixt.	W / Fixt.	W per Space or Usage	Fixture Code	W / Fixt.	W per Space or Usage	W Saved	Annual Hours	Baseline KWh	Proposed kWh	kWh Savings
Janitorial	F42EE	1	72	72	F42LL	62	62	10	772	56	48	8
Janitorial	F44EE	3	144	432	F44LL	110	330	102	772	334	255	79
Janitorial	F42EE	4	72	288	F42LL	62	248	40	772	222	191	31
Private Offices	F42EE	2	72	144	F42LL	62	124	20	2121	305	263	42
Private Offices	F44EE	2	144	288	F44LL	110	220	68	2121	611	467	144
Private Offices	F42EE	2	72	144	F42LL	62	124	20	2121	305	263	42
Private Offices	F44EE	2	144	288	F44LL	220	220	68	2121	611	467	144
Private Offices	F44EE	4	144	576	F44LL	110	440	136	2121	1,222	933	289
Restrooms	F42EE	4	72	288	F42LL	62	248	40	4085	1,177	1,013	163
Total		24		2,520			2,016	504		4,843	3,900	943

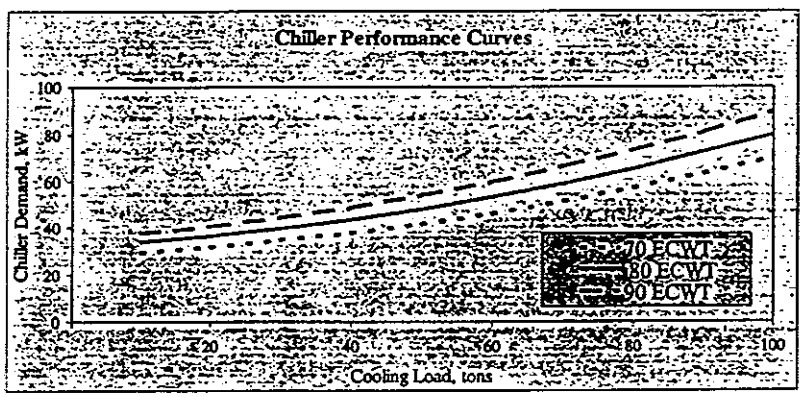
Chiller: Plant Diagram



Chiller: Theory

- Chillers are variable load devices.
- Primary influences are load fraction and condenser water temperature.
- CWR temperature influenced by weather conditions and tower operation.

Chiller: Performance Curves

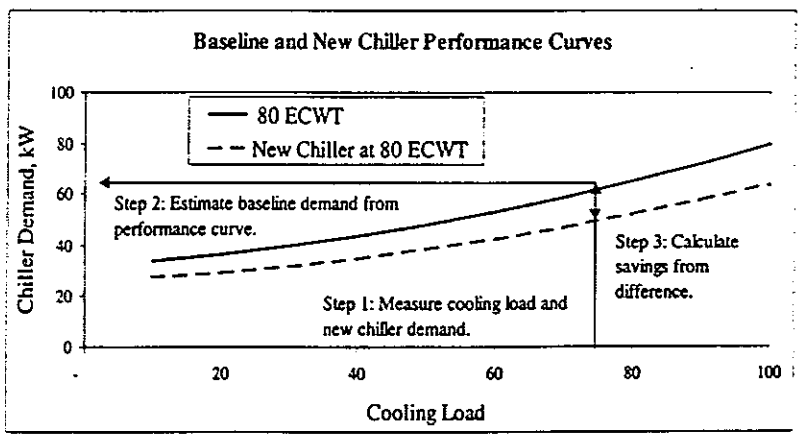


Chiller: Calculating Performance

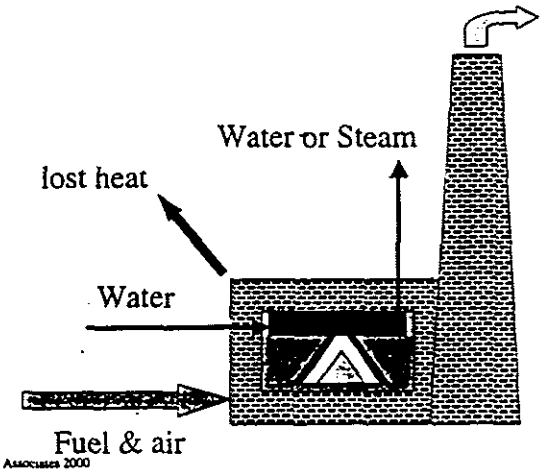
- Need to calculate chiller curves
- Chillers rated in kW/ton of cooling
  - 1 ton = 12,000 BTU/h (~ 1 window unit)
- Old chillers: 0.7 to 1.2 kW/ton
- New chillers: 0.5 to 0.7 kW/ton

$$tons\ cooling = \frac{(T_{Chilled\ water\ supply} - T_{Chilled\ water\ return})(GPM)}{24}$$

Chiller: Estimating Savings



Boiler: Theory



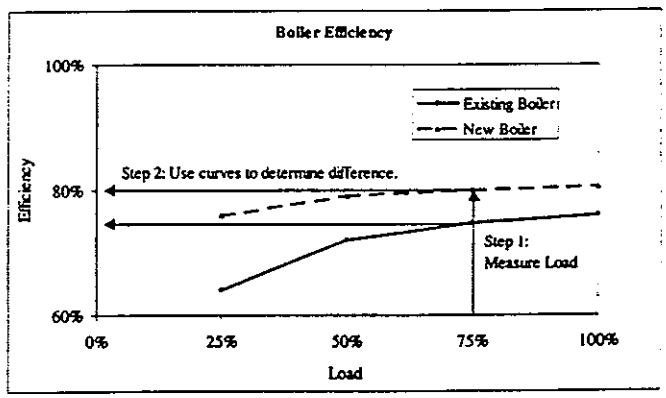
Boiler: Theory

- Boilers provide either hot water or steam for heating.
- Combustion (flames) heat water in tubes to produce hot water or steam.
- Energy source is #6, #2 oil or natural gas.
- Efficiency determined by amount of steam produced per unit of fuel.

Boiler: Measurements

- Boilers are variable-load devices.
- Efficiency decreases with decreasing load.

Boiler & Furnace Performance



Case Study: Industrial Sector

Variable Speed Drives on Ventilation
& Humidification Fans

Project Goals and Objectives

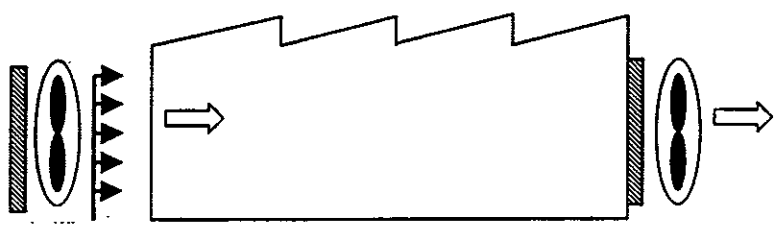
- Project goal: Obtain energy cost savings by installing 15 VSDs on fan motors that are used for ventilating at a fabric factory's production area
- M&V goal: To determine the energy savings during a 10-year performance contract

Facility Characteristics

Facility:

- Large cotton cloth manufacturing facility
- Need to keep facility's humidity constant for the production process
- Humidity and ventilation rates controlled by 15 supply and exhaust fans (total 550 hp) and air wash systems
- Before VSDs, manual (and hard to use) inlet and outlet vanes were used to regulate air flow
- Vanes have 7 different positions and apparently were adjusted seasonally

System Description



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ECM Characteristics

Install VSDs on fan motors to provide:

- Savings by more efficiently controlling fan speed
- Better process control by making it easier to change ventilation rates

Data Products and Output

Information required:

- Verification
  - Motor nameplate data
  - VSD nameplate data
  - Annual inspection results
- Determining savings
  - Baseline motors' kW draw (as a function of ?)
  - VSD controlled motors' kWh draw per year.
  - Baseline kWh was to be based on a model of fan motor kW as a function of air flow.
  - Measurements showed constant kW more realistic.

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Approach, Data Analysis Procedures and Algorithms

- Savings = (annual **post-installation kWh**) minus (annual **baseline kWh**)
- Post-installation frequency metered continuously, then converted to kW.
- For QC, data would be checked first daily, then weekly, then monthly. Independent spot power measurements for calibration.
- Baseline calculation data:
  - calibration data
  - VSD parameters (e.g., *speed, operating hours*)
  - independent variables?

Approach, Data Analysis Procedures and Algorithms

- Baseline model defined with fans in each damper position. Air flow rates monitored and a correlation developed, power = f (flow).
- However, no clear correlation between the dampers' position to the power draw or flow (the dampers leaked).
- In addition, using measurements taken randomly over a nine-month period showed that the baseline could be considered constant (Table 1).

Table 1. Baseline Fan Load Information

FAN	8/22/94	10/24/94	11/6-18/94	FAN FULL LOAD POWER, KW	PERCENT LOAD	AVERAGE	MINIMUM	MAXIMUM
RF-2 KW	14.1	18.9	20	19	89%	17.7	14.1	20.0
RF-3 KW	19.2	20.1	20	19	89%	19.8	19.2	20.1
RF-4 KW	11.1	11.7	13	12	87%	11.9	11.1	13.0
RF-5 KW	12.7	12.6	13	12	87%	12.8	12.6	13.0
RF-6 KW	20.2	23.4	23	22	77%	22.2	20.2	23.4
RF-7 KW	21.2	23.7	22	25	74%	22.3	21.2	23.7
RF-8 KW	13.4	13.2	14	13	94%	13.5	13.2	14.0
RF-9 KW	14.4	15.8	16	21	71%	15.4	14.4	16.0
SF-2 KW	23.5	23.1	23	23	77%	23.2	23.0	23.5
SF-3 KW	32.9	21.6	22	25	74%	25.5	21.6	32.9
SF-4 KW	33.8	33.3	34	37	91%	33.7	33.3	34.0
SF-5 KW	30.4	30.3	25	37	67%	28.6	25.0	30.4
SF-7 KW	12.5	12.6	14	21	63%	13.0	12.5	14.0
SF-8 KW	31	29.1	32	41	71%	30.7	29.1	32.0
SF-9 KW	38.7	36.9	37	33	99%	37.5	36.9	38.7
SUM	329.1	326.3	328	360		327.8	307.4	348.7

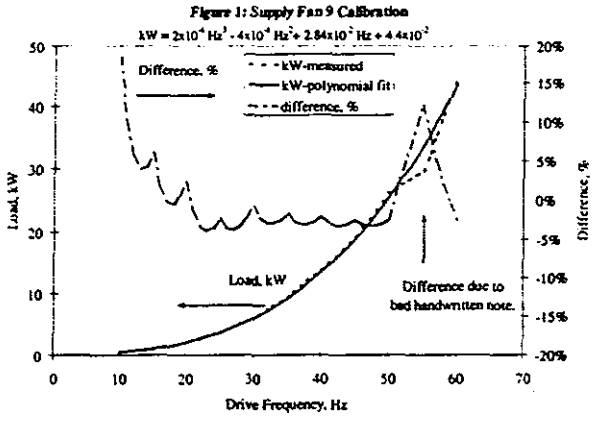
Approach, Data Analysis Procedures and Algorithms

- Thus, a constant baseline kW value was used based on averages of measurements taken continuously over a two-week period.
- For QC, independent spot power measurements were taken.

Data Monitoring

- VSD has a power output indicator, but it is not accurate.
- Speed was a direct indicator of kW.
- VSD could output speed (Hz) and that was recorded via modem at a central computer.
- Calibration curves were created by recording the readings from a power meter while the drive was run through its range from 10-60 Hz (Figure 1).
- Each drive/motor was monitored continuously. Every 15 minutes, the frequency was recorded. Data were converted to kWh using calibration curve.

Figure 1: VSD Calibration Curve



Baseline and VSD Calibration

- Contractor calibrated data loggers with factory calibrated and certified meter.
- Owner spot checked the contractor's power measurements with calibrated power meter.

Results

- Analysis showed:
  1) The calibration curves showed a flaw in one motor's power meter calibration (Figure 1).
  2) The power readings vary so slowly that the recording interval could be lengthened to once a week.
  3) Frequency was more reliable indicator of energy than kWh output, but system would require recalibration if fans changed.
- Table 3 lists the first year estimated and actual energy savings.

Table 3. Estimated and Actual Energy Savings

Fan	Baseline Demand, kW	Post-Retrofit Demand, kW	Energy Savings, kWh	Savings, kWh	Actual Savings / Estimated Savings
SF-2	23	1.8	170,986	185,581	109%
SF-3	23	9.9	76,848	114,398	149%
SF-4	34	23.2	113,601	94,588	83%
SF-5	30	23.7	83,530	57,932	69%
SF-7	14	2.5	67,826	100,867	149%
SF-8	32	18.7	106,918	116,569	109%
SF-9	37	5.3	188,527	277,649	147%
RF-2	20	5.1	66,824	130,313	195%
RF-3	20	9.3	101,907	93,891	92%
RF-4	13	6.2	33,663	59,381	176%
RF-5	13	6.8	66,239	54,426	82%
RF-6	22	5.9	112,506	141,204	126%
RF-7	22	5.5	73,506	144,352	196%
RF-8	14	0.9	71,335	114,331	160%
RF-9	16	1.0	105,582	131,551	125%
Total	333	126	1,439,798	1,817,054	126%
			$ 71,990	$ 90,853	$ 18,863

Conclusions

- Long-term monitoring provided accurate savings estimates.
- Rigorous M&V revealed 26% more savings than originally estimated.
- M&V costs reduced by reducing data collection interval without sacrificing reliability.

Case Study: Industrial Sector

New Regenerator for Milk
Pasteurization Process

Project Goals and Objectives

- Reduce energy use (kWh) and demand (kW) associated with mechanical cooling of processed milk.
- Anticipated savings: 53 kW and 230,000 kWh.
- M&V Goal: Verify energy and demand savings (kW & kWh) for utility incentive payment.

Facility Description

- Dairy processing facility in Colorado. Built in 1959. Manufactures milk, ice cream, and yogurt. Also blow-molds milk jugs on-site.
- Pasteurizer uses high-temperature short-time processing to sterilize milk.
- Regenerator replaced with higher-efficiency model to recover more heat, thereby reducing cooling load.

Measure Characteristics

- New regenerator would recover more heat from pasteurized milk. Reduces need to heat incoming milk and reduces need for subsequent cooling.
- Project expected to cost $100,000 (Rs 3.8 million) and save $10,000 (Rs 380,000) annually. SPB = 10 years.

M&V Approach: Option A

- To determine savings, short-term measurements were made of flowrates, temperatures, and operating conditions.
- Savings a function of production only- all other parameters are fixed.
- Option A (stipulations with measurement) seemed appropriate for this measure.

Required Information

Milk Prodction

- Flowrate, liters/month bottled.
- Temperatures and temperature setpoints.

Equipment

- Chiller performance (COP)
- Boiler efficiency

Measurements Taken

- Temperatures at outlets of regenerator (T2, T4)
- Milk flowrate (L/min)

Assumptions

- Milk flow rate is constant.
- Milk specific heat is (3.9 kJ/kg °C)
  (ASHRAE Fundamentals Chapter 30.3 - Thermal Properties of Foods)
- Milk density is 1 Kg/L
- The COP of the chiller plant is 3.0.
  (based on manufacturer's data for design point operating conditions averaged for all of the refrigeration system's existing compressors.)
- Boiler efficiency is 80%.
  (based on manufacturers' specifications)

Approach and Data Analysis

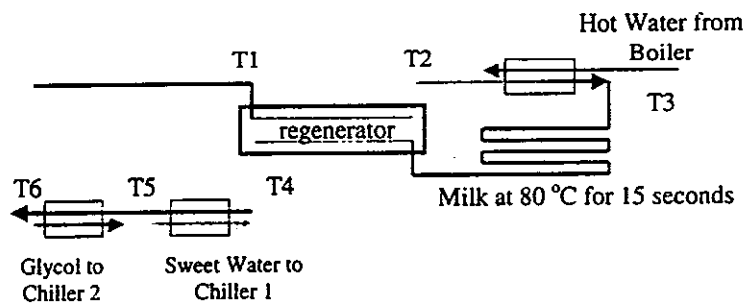
- Baseline is current equipment performance.
- Baseline will be adjusted for production.
- Savings will be calculated as:

$$kW_{saved} = kW_{pre} - kW_{post}$$

$$kWh_{saved} = kWh_{pre} - kWh_{post}$$

$$GJ_{saved} = GJ_{pre} - GJ_{post}$$

High-Temp Short-Time Process



Governing Equations

- Chiller demand is found as:

$$kW = \frac{\dot{V} \times \rho \times C_p \times (T_{in} - T_{out})}{COP}$$

- Chiller energy use is found as:

$$kWh = \frac{V \times \rho \times C_p \times (T_{in} - T_{out})}{COP}$$

- Boiler energy use is found as:

$$GJ = \frac{V \times \rho \times C_p \times (T_{out} - T_{in})}{\zeta}$$

Relevant Parameters

	Base Case	New Conditions	Units
Milk Flowrate	33,000	24,000	L/Hr
T1 (from storage)	4.4	4.4	C
T2 (from regenerator)	73	75	C
T3 (fixed- from heater)	80	80	C
T4 (from regenerator)	10.5	8.9	C
T5 (after cooling stage 1)	4.4	4.4	C
T6 (fixed- after cooling stage 2)	1.1	1.1	C
Hot Water Flowrate	1,040	700	L/mn
HW Entering	81	81	C
HW Leaving	78	78	C
Sweet Water Flowrate	660	418	L/mn
SW Entering	1	1	C
SW Leaving	5.5	5.5	C
Glycol Flowrate	535	465	L/mn
G Entering	-3	-2	C
G Leaving	0.6	1.1	C

Results

Hours per Year	4,355	4,355	4,355		Hours
Cooling Load	336	244	203	42	kW thermal
COP	3	3	3		
Chiller Demand	112	81	68	14	kW electrical
Chiller Energy Use	487,833	354,787	294,398	60,389	kWh
Cost ($0.03/kWh + $12/kW/mo)	$30,765	$22,375	$18,566	$3,808	
Heating Load	3,923	2,853	2,038	815	GJ
Boiler Efficiency	80%	80%	80%		
Heating Energy Use	4,904	3,567	2,548	1,019	GJ
Cost ($4.75/GJ)	$23,295	$16,942	$12,101	$4,841	
Total Cost Savings				**$8,649**	

Conclusions

- Savings a little short of original estimates, but justification exists for values.
- Since many parameters are fixed, only a few values need to be monitored. Savings most heavily influenced by production and T4 (temperature prior to cooling).
- Option A appropriate for project size and type.

Measurement & Verification protocol Industrial - India

INTESCO Asia Limited
114 Ulsoor Road Cross Bangalore 560 042
www.intescoasia.com

Outline

- IPMVP - a quick recap
- Suitability and applicability of IPMVP
- Best application situations
- Issues
- Case example

IPMVP - a quick recap

- Why measure & verify?
- Benefits of M&V
- The key to unlocking the potential for energy efficiency world-wide is securing financing.
- M&V provides confidence needed to secure funding for projects

IPMVP - a quick recap (contd.)

- What does IPMVP provide?
- Helps in selection of M&V approach that best matches project cost and savings magnitude, risk allocation

Suitability & Applicability

- Basic Concept
- Options A,B,C & D
- The M&V costs and the associated benefits, risk value of stipulation would enable choosing between Option A & Option B

Best Application Situations

- Retrofit Isolation with energy efficient design- Option A
- control system projects - Option B

Issues

- Measurement Intervals
- Boundary line
- Inaccuracies in base-line data
- Uncertainty Versus M&V Costs
- Financial Institutions prefer minimized risks, even if M&V costs are more.

Measurement issues

- Measurement techniques
- Calibration
- Data Collection errors

Case Example: Industrial

Compressed air system efficiency Improvement through a control system in a textile mill (spinning & weaving)

Project Goals & Objectives

- Project Goal: Obtain energy cost savings in the compressed air system by installing a control system
- M&V Goal: To measure and verify the savings

Facility Characteristic

- Spinning & Weaving mill
- Compressed air largely (over 85%) used in air-jet looms for weaving
- Production monitored as lakh metre of cloth
- Energy meters available for the centrifugal air compressors

System Description

- Install a control system located between the compressor and the end-use location

ECM Characteristic

- Artificial demand reduction as cfm load on the air-compressors achieved by designing a system with adequate storage capacity, set-point end-use pressures reflecting as kWh savings.

Data Products & Output

- Information Required
- Verification
- Energy consumption in air-compressors
- Determination of Savings
- Energy use in air-compressors base year & post-retrofit brought to same conditions by relating kWh to production

Approach Data Analysis Procedures & Algorithms

- cfm/hp stipulated as compressors remain same during base year and post-retrofit conditions
- cfm measurement difficult & expensive
- kWh meters & production as lakh m available. Spot measurements done for kWh
- System boundary line Compressor motor

Approach Data Analysis Procedures & Algorithms

- Base year consumption - kWh/lakh metre of cloth
- New addition of looms during post retrofit is taken care of by kWh-production ratio.
- Subsequent to implementation, during post-retrofit, the lakh metre of all clothes is not similar in terms of compressed air use was brought to notice.

Non-routine Adjustment

- Production in the shop-floor is monitored as million picks per day for which purpose, compressed air is used in these looms.
- The energy meter data is logged for each of the compressors on a daily basis. The kWh/lakh metre of cloth was changed to kWh/MPPD (million picks per day) & base-line conditions also drawn up in same way.

Results

- The approach led the plant monitor the savings on a daily basis.
- The overall consumption came down by 4600 kWh a day
  from 375 kWh/MPPD to 329 kWh/MPPD
  (MPPD-Million Picks Per Day)
- It also provided flexibility in terms of monitoring on weekly or monthly basis.

Case Study: Commercial Sector

Large Office Lighting Efficiency

Project Description

- Lighting upgrade project at large office in California. Equipment installed included:
  - T8 fluorescent lamps and electronic ballasts
  - Occupancy sensors

Project Goals

- Achieve 192 kW of demand reduction and 1.1 million kWh in energy savings.
- Receive utility incentive payments for three years to reduce project cost.

M&V Approach

- M&V approach set by utility company.
- Monitoring fixture operating hours for three years (Option B).
- Monitoring precision set by utility company: 20% precision at 80% confidence.
- Fixture powers set by utility company- no power measurements taken.

M&V Procedures

- Take fixture inventory and identify the last point-of-control (switch).
- Identify non-operating fixtures.
- Use approved lighting table to determine fixture power.
- Identify usage groups.

Typical Fixture Powers

FIXTURE CODE	LAMP CODE	DESCRIPTION	BALLAST	LAMP/ FIXT	WATT/ LAMP	WATT/ FIXT
F42SE	F40T12	Fluorescent, (2) 48", STD lamp	Mag-ES	2	40	86
F42EE	F40T12/ES	Fluorescent, (2) 48", ES lamp	Mag-ES	2	34	72
F42LL	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	60
F43SE	F40T12	Fluorescent, (3) 48", STD lamp	Mag-ES	3	40	140
F43EE	F40T12/ES	Fluorescent, (3) 48", ES lamp	Mag-ES	3	34	115
F43LL	F32T8	Fluorescent, (3) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	3	32	93
F44SE	F40T12	Fluorescent, (4) 48", STD lamp	Mag-ES	4	40	172
F44EE	F40T12/ES	Fluorescent, (4) 48", ES lamp	Mag-ES	4	34	144
F44LL	F32T8	Fluorescent, (4) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	4	32	118

This is an excerpt from the Southern California Edison lighting table used for the Standard Performance Contracting DSM program.

Usage Groups

- Need to define usage group by function to determine operating hours. Examples:
  - Office space
  - Conference room
  - Storeroom
  - Safety (fire stairs, exit signs, all other 24/7)
  - Exterior

Sample Size

- Need to determine sample size for each usage group based on population and precision criteria.
- If coefficient of variation is not known, need to assume value. Use 0.5 for office lighting.

$$C_v = \frac{std.\ dev.\ of\ hours}{average\ of\ hours} = 0.5\ (assumed)$$

Determining Sample Size

- 20% precision at 80% confidence required. (Z = 1.282, P = 0.2)
- Initial sample size is: $$n = \frac{Z^2 \ C_v^2}{P^2}$$
- After adjusting for population size N: $$n^* = \frac{(Nn)}{(N+n)}$$

Sample Size Table ($C_v = 0.5$)

Precision	**20%**	20%	10%
Confidence	**80%**	90%	90%
Z-Statistic	**1.282**	1.645	1.645
Population Size, N	Sample Size, n*		
20	**8**	10	16
50	**10**	13	29
100	**10**	15	41
200	**11**	16	51
500	**11**	17	60
infinite	**11**	17	68

More precision requires more samples!

Initial Sample Size

Usage Group	Use	kW saved	Population	Sample Size	Annual Hours (est.)	kWh Saved (est.)
A	Open Office	16.1	29	8	4,050	65,205
AS	Open w/ Sensor	34.8	145	11	4,050	193,686
B	Private Office	15.9	25	8	4,050	64,395
BS	Private w/ Sensor	84.8	622	11	4,050	484,466
C	Utility	6.9	33	9	2,013	13,890
CS	Util w/ Sensor	2.7	16	7	2,013	7,690
D	Exit/Emergency	2.3	30	9	8,760	20,148
E	Hallways, Stairs, Restrooms	26.1	54	10	8,760	228,636
ES	Hall w/ Sensor	4.0	22	8	8,760	41,862
	Total	**193.6**	**976**	**81**		**1,119,977**

Baseline for Motion Sensors

- The ESCO- in their haste to implement the project- never characterized the baseline operating hours of fixtures where motion sensors were to be added.
- Problem: How to define baseline hours ***after*** sensors were installed?
- Solution: Make ***control*** group by disabling some sensors.

Modified Sample Size

Usage Group	Use	kW saved	Population	Sample Size	Annual Hours (est.)	kWh Saved (est.)
A	Open Office	16.1	29	8	4,050	65,205
AS	Open w/ Sensor	34.8	145	25	4,050	193,686
AS	**Open w/ Sensor (CONTROL)**			25		
B	Private Office	15.9	25	8	4,050	64,395
BS	Private w/ Sensor	84.8	622	35	4,050	484,466
BS	**Private w/ Sensor (CONTROL)**			35		
C	Utility	6.9	33	0	2,013	13,890
CS	Util w/ Sensor	2.7	16	0	2,013	7,690
D	Exit/Emergency	2.3	30	0	8,760	20,148
E	Hallways, Stairs, Restrooms	26.1	54	8	8,760	228,636
ES	Hall w/ Sensor	4.0	22	12	8,760	41,862
ES	**Hall w/ Sensor (CONTROL)**			6		
	Total	**193.6**	**976**	**162**		**1,119,977**

Monitoring Operating Hours

- Time-of-use loggers were installed in random locations for 3 weeks.
- Control samples had motion sensors disabled (reverted to switch operation).
- Following logging, precision checked to see if it met 80%/20% criteria.

Metering Results

Usage Group	Use	Population	Sample Size	Measured Operating Hours	Standard Deviation	Cv	Precision @ 80% Confidence
A	Open Office	29	7	3,333	3,269	0.98	41%
AS	Open w/ Sensor	145	25	2,906	3,148	1.08	25%
AS	Open w/ Sensor (CONTROL)		25	4,782	3,047	0.64	15%
B	Private Office	25	7	5,069	3,749	0.74	30%
BS	Private w/ Sensor	622	35	1,065	998	0.94	20%
BS	Private w/ Sensor (CONTROL)		35	5,047	2,837	0.56	12%
C	Utility	33	0				
CS	Util w/ Sensor	16	0				
D	Exit/Emergency	30	0				
E	Hallways, Stairs, Restrooms	54	8	5,999	2,875	0.48	20%
ES	Hall w/ Sensor	22	12	3,174	1,801	0.57	14%
ES	Hall w/ Sensor (CONTROL)		6	6,602	3,166	0.48	21%
	Total	976	160				

Savings Calculations

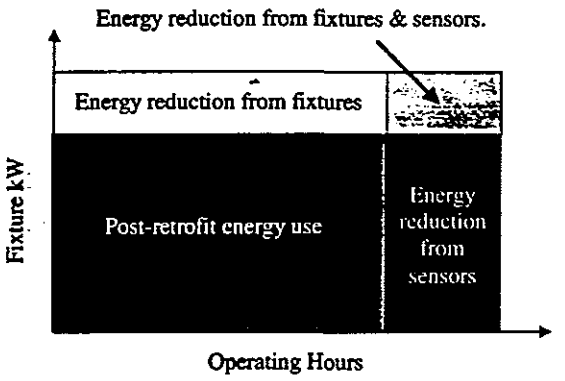
- For fixture upgrades, savings are based on post-retrofit operating hours only.

$$kWh_{saved} = Hours_{measured}\,(kW_{pre} - kW_{post})$$

- For fixture upgrades & occupancy sensors, savings are based on pre- & post-retrofit hours.

$$kWh_{saved} = kW_{pre}Hours_{control} - kW_{post}Hours_{measured}$$

Savings Calculations (cont'd)



Savings Results

Usage Group	Use	pre kW	post kW	Control Operating Hours	Measured Operating Hours	Savings, kWh	* Savings, %
A	Open Office	39.6	23.5		3,333	53,809	41%
AS	Open w/ Sensor	78.2	43.4	4,782	2,906	247,806	66%
B	Private Office	30.6	14.7		5,069	80,531	52%
BS	Private w/ Sensor	201.0	116.2	5,047	1,065	890,593	88%
C	Utility	11.4	4.5		2,013	13,817	60%
CS	Util w/ Sensor	6.4	3.6	2,013	1,409	7,690	60%
D	Exit/Emergency	3.0	0.7		8,760	20,244	76%
E	Hallways, Stairs, Restrooms	47.1	21.0		5,999	156,721	55%
ES	Hall w/ Sensor	6.7	2.7	6,602	3,174	35,509	80%
	Total	**424**	**230**			**1,506,722**	**73%**

* relative to baseline

Conclusions

- Power measurements eliminated through the use of a standard table- reduces cost & increases consistency.
- Hour measurements show 'true' energy savings- 34% more than originally estimated.
- Baseline established through the use of a ***control group***.

Case Study: Commercial Sector

Comprehensive Office Building
Project

Project Description

- Large office building in California of large aerospace contractor. Project included:
  - Lighting efficiency upgrades
  - Constant-Volume Dual-Duct air handlers converted to Variable-Air Volume w/ VSD
  - Chiller replacement
  - Efficient motors on chilled water pumps
  - New cooling tower

Project Goals

- Reduce total Energy consumption
- Reduce 10,000,000 kWh energy consumption by 20% ($100,000 or Rs 3.8 million per year)
- Improve air distribution to offices
- Replace R-11 chiller with R-134a
- Replace old cooling tower

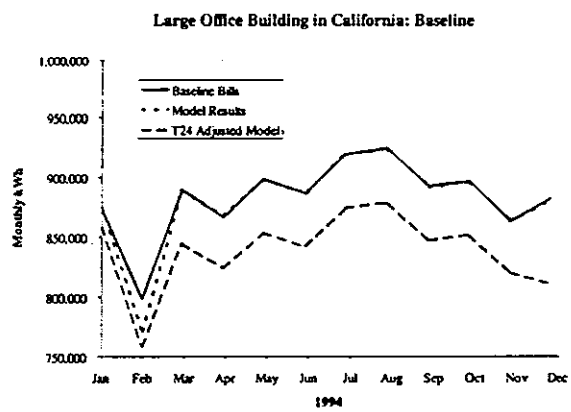
M&V Approach

- Combination of Option C and D used.
- Building simulation model (Option D) used to establish baseline conditions.
- Annual post-retrofit utility bills (Option C) used to determine post-retrofit performance.
- Difference is savings
- Savings to be tracked for 3 years.

Baseline Definition

- Building simulation model developed and calibrated to monthly utility bills.
- California has minimum energy-efficiency standards called Title 24.
- New model developed incorporating energy-efficiency standards.

Building Model Comparison



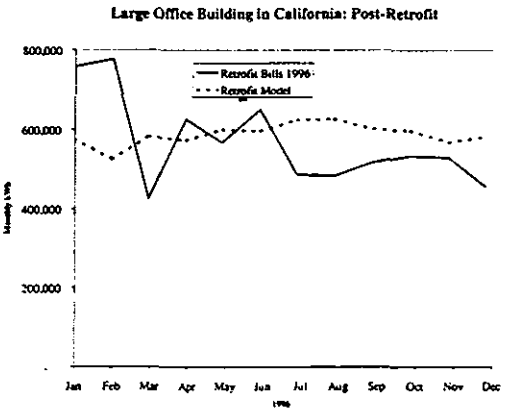
Savings Calculations

- Results from Title 24 model adjusted for weather.
- Title 24 model adjusted for other factors.
- Actual utility bills subtracted.
- Difference is savings.

Model Verification

- Retrofit model developed and adjusted.
- Utility bills compared to retrofit model
- Significant difference indicate problem

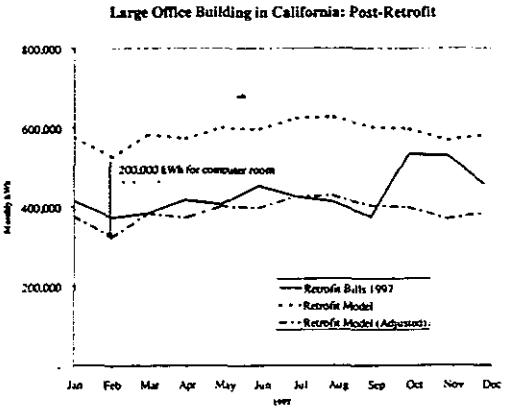
Post-Retrofit Performance



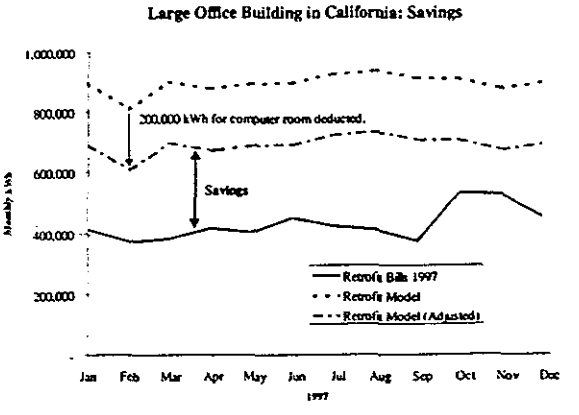
Problems Noted

- Construction completed January 1996.
- Project being commissioned through early 1996.
- Large computer room removed (loss of load)- accounted for 200,000 kWh/mo.
- Computer room required baseline adjustment.

Baseline Adjustment



Savings Calculations



Conclusions

- Options C and D successfully combined
- Simulation model could be used to estimate baseline case
- Model was adjusted for weather, facility changes, and energy-efficiency standards
- Continued comparison of actual utility bills to post-retrofit model assures long-term performance.

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1 of 19

Outline

- Commercial sector energy use
- Suitability and applicability of IPMVP
- Best application situations
- Issues
- Case example

2 of 19

Commercial Sector energy use

- Commercial sector energy loads
  - Lighting & Fans
  - Air-conditioning
  - Elevators / Escalators

3 of 19

Base year energy use

- Energy Savings Equation
- Base year consumption

4 of 19

Suitability & Applicability

- Options A,B,C & D
- Cost Benefit Tradeoffs
- The M&V costs and the associated benefits, risk value of stipulation would enable choosing between Options A to D for each of the ECM

5 of 19

Best Application Situations

- Retrofit Isolation with energy efficient design- Option A
- Post-retrofit variable operating hours due to VSD, control system projects - Option B
- Whole billing/ building - Option C
- Complex cases - computer Simulation

6 of 19

Common Issues

- Base-year data
- Same meter for multiple loads
- Multi-owner complex with centralized services
- Educating end-users on benefit of using regression, simulation techniques

7 of 19

Case Example: Commercial I

An energy efficiency project for a software research centre in an university

8 of 19

Project Goals & Objectives

- Project Goal: Obtain energy cost savings in the software research centre
- M&V Goal: To measure and verify the savings

9 of 19

Facility Characteristic

- Computer Research and Education centre with air-conditioning load of 150 TR
- Area of 50,000 sq.ft
- Used by students 24 hours throughout the day across the year
- Short term programs also organized in conference room, a part of the centre

10 of 19

System Description

- Reciprocating chillers
- manually controlled
- damper controlled Air Handling Units (AHU)
- Distinct variations in energy use due to seasonal changes

11 of 19

ECM Characteristic

- Upgrade chillers
- Enhance lighting efficiency with ballasts and controllers
- Retrofit state-of-the-art cost effective Building Automation System (BAS)

12 of 19

Data Products & Output

- Information Required
- Verification
- Energy consumption
- Determination of Savings
- Energy use in base year & post-retrofit brought to same conditions by relating kWh to weather conditions

13 of 19

Approach Data Analysis Procedures & Algorithms

- Whole billing
- System boundary line Computer centre
- kWh meters available
- Spot measurements

14 of 19

Approach Data Analysis Procedures & Algorithms

- Base year consumption
- Regression equation developed linking weather data, computer users and energy use.
- From computer logs, number of users and hours of use arrived during a month

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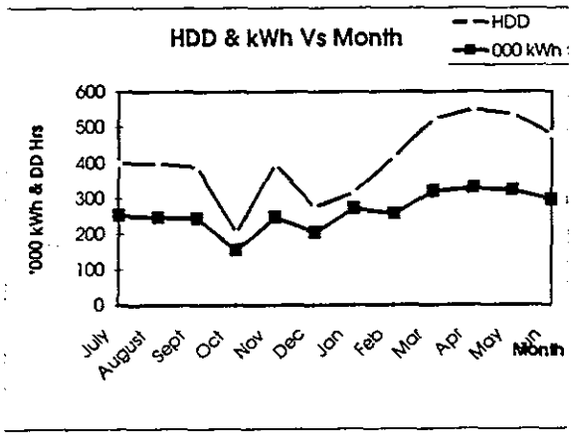
Approach Data Analysis Procedures & Algorithms



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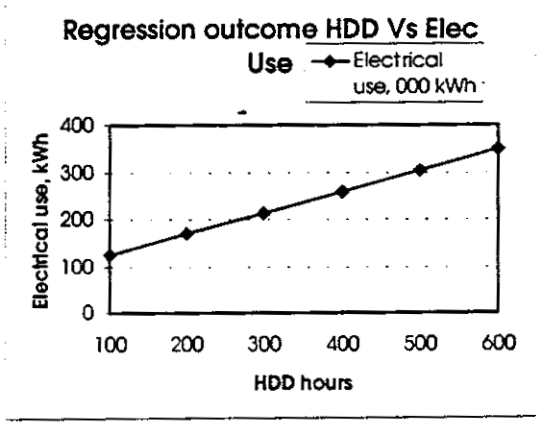
Approach Data Analysis Procedures & Algorithms



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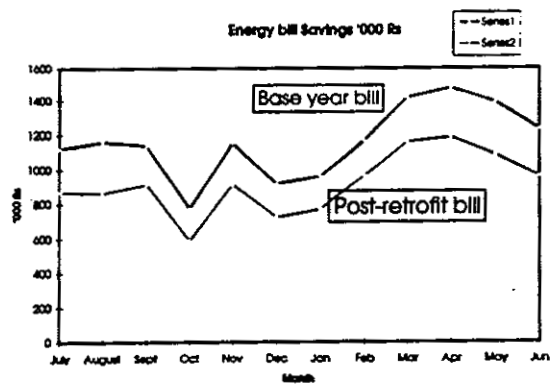
EB Energy Bill Savings



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Results

- The approach enabled a pragmatic way to measure & verify the savings using Option C. (Whole billing method)

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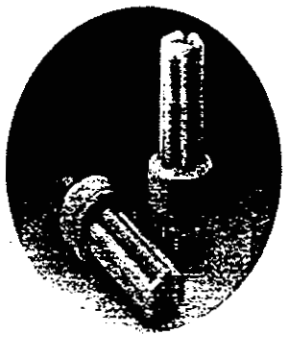
Case Study: Residential Sector



Compact Fluorescent Lamp

Mail-Order Program

Program Goals

- Utility-sponsored program to reduce system electrical demand
- Increase penetration of compact fluorescent lamps into residential and small-commercial sector
- Implemented by third-party
- Payments based on kW and kWh savings achieved

150

Program Approach

- Third-party would sell compact-fluorescent lamps at prices below retail
- Sales would be mail-order based
- Marketing through utility-bill inserts

Savings Goals

- Sell 4,000 bulbs/year for three years to residential sector.
- Sell 6,000 bulbs/year for three years to small commercial sector.
- If fully implemented, program would save 3.5 million kWh and reduce system demand by 266 kW annually.

M&V Approach: Option A

- Short-term metering on a sample of homes (and businesses) to determine operating hours.
- Extrapolate results to all homes (and businesses), stipulate operating hours.
- Use phone surveys of participants to gage compliance and satisfaction.

Results

- Metering not performed- bulbs assumed to operate 2,000 hours per year.
- Phone surveys not yet conducted.
- Diversity factor assumed to be 15% for calculating demand savings

Results to Date

Existing Lamp (Assumed), W	CFL, W	Savings, W	Diversity Factor	Operating Hours	Quantity Sold	kW Saved	kWh Saved
60	15	45	15%	2,000	2,382	16.1	214,380
60	20	40	15%	2,000	1,735	10.4	138,800
100	23	77	15%	2,000	2,666	30.8	410,564
100	26	74	15%	2,000	1,015	11.3	150,220
Total					7,798	68.5	913,964

Projected Results

Existing Lamp (Assumed), W	CFL, W	Savings, W	Diversity Factor	Operating Hours	Quantity Sold	kW Saved	kWh Saved
60	15	45	15%	2,000	7,500	51	675,000
60	20	40	15%	2,000	7,500	45	600,000
100	23	77	15%	2,000	7,500	87	1,155,000
100	26	74	15%	2,000	7,500	83	1,110,000
Total					30,000	266	3,540,000

Problems Encountered

- Original proposal called for monitoring a sample of homes for operating hours.
- Monitoring costs considered too high.
- Solution: Assume and stipulate operating hours
- Result: Risk transferred back to sponsoring utility- could be paying too much for savings.

Problems Encountered

- Diversity Factor: Probability that demand savings occur during peak demand hours.
- With no monitoring, it is impossible to calculate diversity factor.
- Solution: Assume and stipulate factor
- Result: Utility assumes risk- could be paying too much for demand savings

Conclusions

- Option A (stipulation) provided lowest-cost approach.
- Lack of measurements increased risk to sponsoring utility.
- Utility cost-recovery at risk.

Case Study: Residential Sector

Replacement of air conditioners and furnaces with ground-source heat pumps at military housing.

Project Description

- Replace old DX air conditioners and furnaces (gas & oil) with ground source heat pump.
- Savings come from significantly increased cooling efficiency in summer (COP 4-6.5) and heating cost savings.
- Savings also from reduced maintenance efforts.

Facility Description

- Military District of Washington comprises five military bases near Washington, D.C.
- Multifamily housing for soldiers and their families.
- Housing built in 1940's and has historic value that needs to be preserved.

Project Financing

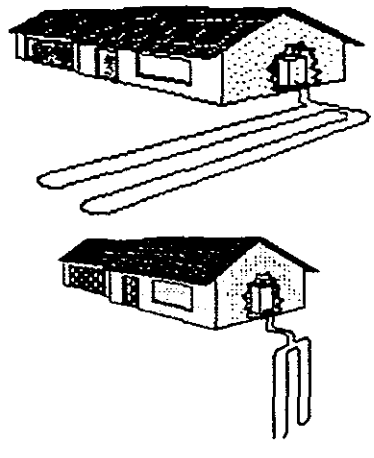
- Performance contract with U.S. Department of Defense will provide $67 million (Rs 2.5 billion) of capital investment.
- 18 Year contract- paid from savings.
- GSHP measure is one of a dozen being installed at the five bases. Investment is $2.65 million (Rs 100 million).

Ground-Source Heat Pump

- Similar to central air-conditioning system in that system uses refrigerant (R-22) and mechanical compressor.
- Can provide both heating and cooling by reversing refrigerant flow.
- Heat is extracted or rejected to soil instead of atmosphere.

GSHP Configurations

- Ground-source heat pumps exchange heat with the soil.
- Usually PEX tubing circulating glycol.
- Either just below surface or deep wells (30-100 m).



M&V Approach

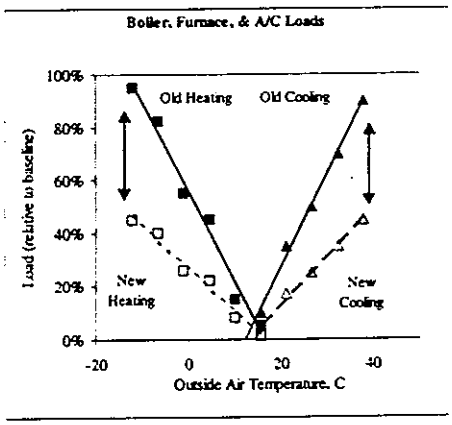
- Hybrid of Option B and A
- Use short-term metering (one season) to characterize a sample of heating and cooling equipment (Option B).
- Normalize results to typical weather.
- Install GSHPs

M&V Approach (cont'd)

- Monitor performance for one year. (Option B)
- Normalize to typical weather conditions.
- Compare differences.
- Stipulate weather conditions (Option A).
- Remonitor heat pumps every three years to verify performance.

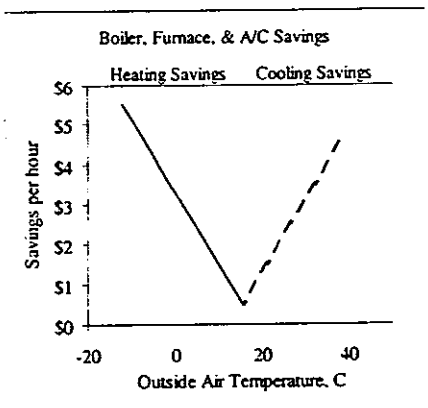
Furnace & A/C Performance

- Short-term measurements to define run-time as function of OSA temp.
- Repeat on heat pumps.
- Savings are the difference.



Furnace & A/C Savings

- Convert savings to dollar amounts because of fuel switching.
- Develop equations for savings as a function of temperature.



M&V Issues

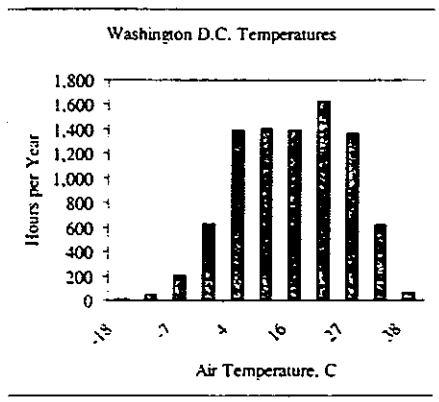
- Need to ensure that sampling periods are sufficient for both heating and cooling.
- Need to use correct fuel prices for oil, gas, and electricity.
- Demand savings apply to summer only.
- Savings not based on real weather data but typical weather data.

Conclusions

- Method could could be considered hybrid Option A & B, or simply Option A with measurements.
- Savings based on *measured* performance and *stipulated* weather data. *Actual* savings will fluctuate every year but *claimed* savings will not.

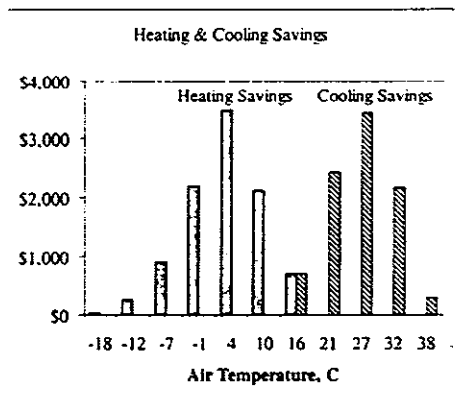
Weather Data

- Need to apply savings to weather data.
- Use TMY data to find hourly temperature distribution.
- Then apply distribution to savings.



Bin Analysis

- For each temperature range, find savings in dollars/hour.
- Multiply savings by number of hours.
- Total savings are sum of bin savings.



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Measurement & Verification protocol Residential - India

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114 Ulsoor Road Cross Bangalore 560 042
www.intescoasia.com

Outline

- Residential-energy end-use
- Suitability and applicability of IPMVP
- Best application situations
- Issues
- Case example

Residential - Energy end-use

- Energy end-use areas in a typical home / apartment buildings
  - Lighting
  - Water pumping
  - Appliances - refrigerator, Television, air cooler
  - Water heating
- Energy inefficiency (Builder Vs Buyer, Tenant Vs Owner)

Load profile

- Lighting
- Water pumping
- Others

Suitability & Applicability

- Lighting upgrade
- Water pumping
- Apartments Common area services
- Colony / Quarters
- Owner Versus Tenant

Best Application Situations

- Retrofit Isolation with energy efficient design- Option A
- Renewable, Fuel switching projects - Option B
- New group housing construction projects - Combination of options.

Common Issues

- Costs associated with monitoring hours of use
- Advantage for SEBs
- Sampling errors
- Maintenance of the energy efficiency components

Case Example: Residential

An energy efficiency project for a
new group housing
construction project

Project Goals & Objectives

- Project Goal: Reap energy cost savings in a new group of houses construction project
- M&V Goal: To measure and verify the savings

Facility & ECM Characteristic

- To provide 6 fluorescent lamp fittings with electronic ballast, 4 CFLs for each house in place of GLS lamps
- Hours of use stipulated
- Solar water heaters for 200 LPD for each house.

ECM Characteristic

- Enhance lighting efficiency with ballasts and controllers
- Avoid electricity towards water heating

Approach Data Analysis Procedures & Algorithms

- Boundary line for lighting - lamp power consumption using portable spot measurement meter.
- Solar water heating spot water temperature measurements at agreed range of ambient temperatures and time of the day.

Results

- The approach enabled achieving energy gains in a pragmatic way and measure & verify the savings using

  Option A & Option B.

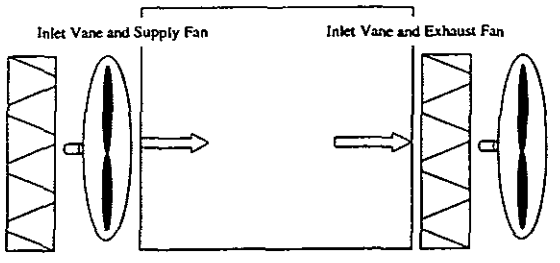
Assignment

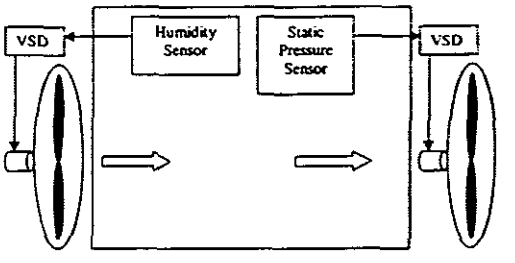
Textile Mill Example #1

Yarn Spinning: Replace standard 15 kW to 22 kW motors of Ring frame machines used in spinning yarn with energy efficient models. The spindle speed varies from 12,000 to 16,000 rpm depending on the count of yarn. Also the speed of the ring frames follow a cyclic pattern (slow at start and again slow during end of the batch) for a single batch called as doff. The speed variation is currently through mechanical systems such as variable sheave pulley. Replacing the mechanical systems with variable frequency drives programmed for various counts will improve the productivity by 5 to 10% and reduces the yarn breakages.

Textile Mill Example #2

Ventilation: A textile plant has large ventilation fans to supply outside air and exhaust factory air. Ventilation requirements are set by the internal relative humidity, which is maintained between 45% and 55%. The present fans are controlled using inlet vanes, which are manually adjusted on a weekly basis to maintain humidity. The fans comprise 5% of the total electrical factory load. Ventilation requirements are only slightly affected by production. To reduce fan motor energy consumption, variable speed drives can be used modulate the fans based on the internal relative humidity. This will reduce fan power relative to the inlet vanes and provide better humidity control.





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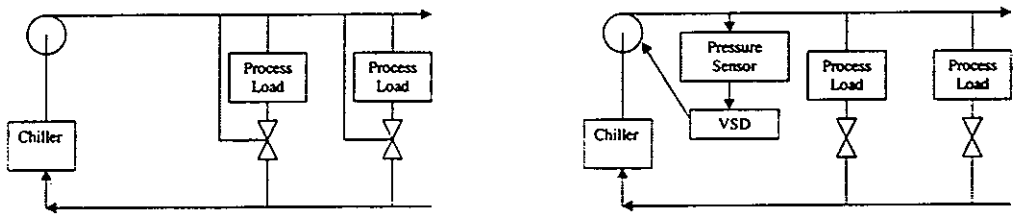
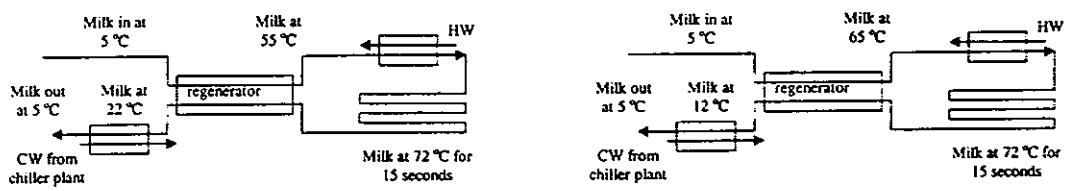
Food Processing Plant Example #1

Chilled Water Pumping: The cooling water pump in an edible oil plant delivers the same quantity of water irrespective of plant load variations. The cooling water system contributes to over 30% of the electrical load. A variable speed drive is proposed to meet the system inefficiency. Currently, three-way valves are modulated to maintain process load temperatures. The proposed design will convert the existing three-way valves to two-way valves and install a pressure sensor downstream of the pump discharge. The VSD will then be used to maintain a constant supply pressure in the chilled water supply instead of a constant flow.



Food Processing Plant Example #2

Heat Recovery: A dairy pasteurizes milk using the High-Temperature Short-Time (HTST) method by heating it to 72 C for 15 seconds. The milk is then cooled to 5 C for bottling with the heat being absorbed by the refrigeration system. It is proposed to upgrade the regenerator (a heat exchanger) so that the milk entering the cold heat exchanger is at a lower temperature. Savings are anticipated from both reduced heating load and reduced cooling load. A gas boiler provides hot water; gas use for this process is 30% of the total use. A central refrigeration plant of COP 3 provides chilled water; chilling the milk takes 50% of the refrigeration capacity. The chiller plant consumes 50% of the plant electricity used.



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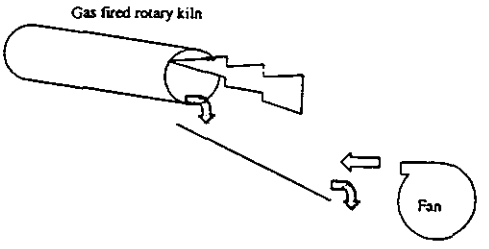
Cement Kiln Example

Product Cooling: A cement plant uses a 1,000 kW motor on a fan to cool the slaked lime as it leaves the rotary kiln. The present motor is old and assumed to be of low efficiency. It is proposed to replace the motor with a new high-efficiency motor. The current motor uses 8,000,000 kWh, about 5% of the plant's electricity. It is anticipated that the motor will save 10% relative to the existing motor, or 800,000 kWh. The fan operates continuously (except for maintenance shutdowns) and its load is independent of production rate.



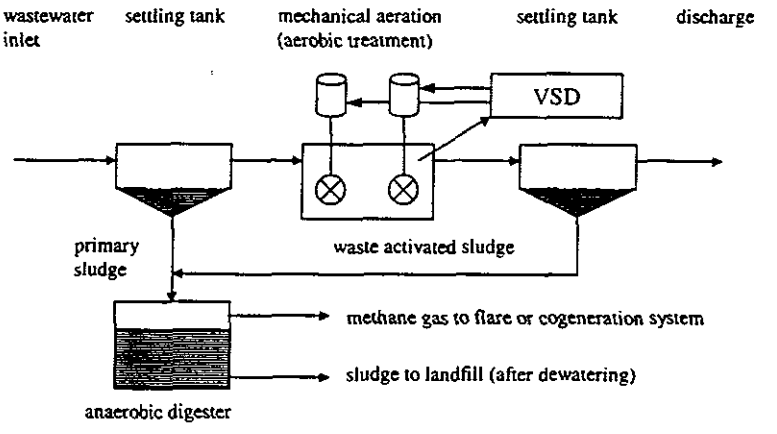
Paper Manufacturing Example

Pulp Processing: One step in the paper manufacturing process is grinding the pulp to the proper consistency. There are eight grinders of 250 kW_m each which operate approximately 5,000 hours per year. It is proposed to replace the existing old motors with high-efficiency motors. The new motors will use 10% less electricity than the existing motors, roughly 1 million kWh saved. The grinder motors comprise 50% of the plant's total electrical consumption. Motor load is a function of the type and the quantity of paper produced. Other plant loads are also influenced by production rate and type of paper being made.

Power Factor Correction: In the paper mill mentioned previously, the power factor is sufficiently low (averaging 0.65 every month) that they are being substantially penalized by the Electrical Board. The ESCO proposes to add an automatic power factor correction capacitor bank at the main plant distribution system. The PF correction will increase their apparent power factor to an average of 0.9.

Wastewater Treatment Plant Example #1

Mechanical Aerators: In a wastewater treatment plant, mechanical agitators are used to aerate the wastewater and promote aerobic bacterial activity. These mechanical agitators presently operate at constant speed and full load independent of the level of aeration required. It is proposed to add dissolved oxygen (D.O.) sensors to the aerobic digestion treatment tank. This signal will control the aerators through variable frequency drives. As the D.O. level increases, the aerator compressors will slow down and save energy. Dissolved oxygen levels fluctuate with system loading, which is a function of local population and a nearby agricultural processing facility that increases the system load during the harvest season(s). The aerators consume 30% of the plant load and adding the VSDs is expected to reduce aerator consumption by 30%.



Wastewater Treatment Plant Example #2

Cogeneration: In the previous example, an ESCO proposes to install an internal-combustion engine cogeneration system to produce hot water and electricity. The methane to operate the generator will come from the anaerobic digester, which is presently flared. The methane can be considered a renewable resource (i.e. free). The generator will displace purchased electricity at the plant. The hot water will be used to heat the anaerobic digestion tank at a constant temperature, which is presently not done. (Heating the anaerobic tank to a constant temperature of 40 °C will have the ancillary benefit of improving sludge digestion and increasing pathogen destruction.) Installing the generator will require the addition of one full-time mechanic to the staff to operate and maintain the generator and related components.

Industrial Sector- Specific Technologies

Steam System: An ESCO proposes to upgrade an existing steam system at an industrial facility. The steam is used for process loads that don't vary significantly over time or with weather conditions. The ESCO proposes the following three upgrades:

1. Replace bucket steam traps with orifice steam traps. The bucket steam traps have a lifetime of five years, but inconsistent maintenance has left the existing system with a number of failed traps. A survey with an infrared thermometer indicated excessive temperatures (> 100 °C) downstream of the steam traps on 20% of the traps, suggesting that they are leaking or failed. Orifice traps have no moving parts and a much longer lifetime. It is expected that the failure rate will be less than 3% with the new traps installed.
2. Repair or add condensate return lines. Some of the condensate is drained instead of being recovered; quite a bit more is lost in the leaking condensate return system. This increases the boiler load, water consumption, and treatment chemicals required. Increasing the condensate return will reduce the requirements for all three.
3. Insulate steam supply and condensate return lines. Almost all of the steam lines are uninsulated, wasting heat. Adding jacketed fiberglass insulation to the steam and condensate lines will reduce heat loss and increase the condensate return temperature.

Compressed Air

As part of a package of services, an ESCO proposes to upgrade and maintain the compressed air system at an industrial facility. Compressed air is used for machine actuators and for hand-tools. A survey with an ultrasonic probe indicates that 30% of the quick-connects that provide air to hand tools are leaking. The ultrasonic probe also indicated leaks in pipe fittings, condensate drains, and some equipment. A leakdown test was used to determine the total leak rate prior to repairing the system. The ESCO will replace the quick-connects and repair the pipe fitting leaks, the factory owner will repair air leaks in its equipment. The ESCO will conduct annual ultrasonic inspections for the next five years and will repair failed quick-connects and pipe leaks. It will notify the owner of air leaks in its equipment so that they can be repaired.

Water

As part of a package of services, an ESCO proposes to replace toilets at a university, both in the classroom buildings and in the dormitories. Toilet flush volume will be decreased from an average of 12 L/flush to 6 L/flush. Dormitory showerheads will also be replaced, reducing flow

per shower from 15 L/min to 7.5 L/min. The university is in session all year (except breaks) and its population is relatively constant.

Commercial Sector

Commercial Office Space: A 20,000 sq. m. office building in Delhi will have a comprehensive set of measures installed. These include:

1. Installing a new energy management & control system. Direct digital control modules will replace the pneumatic actuators now used. Part of the control strategy will include the addition of an enthalpy-controlled economizer to provide cooling when the outside air is cool and dry enough to do so (< 15 °C). The new DDC actuators should also decrease maintenance efforts.
2. The air handler will be converted from dual-duct constant volume to variable-air-volume with variable speed drives on the fan motors. The old fan motors will be replaced with high-efficiency motors designed to operate with VSDs. The VSD will maintain a constant static pressure in the duct. New VAV distribution boxes will be installed.
3. The old 600 kW_T chiller operates with a COP of 4. It will be replaced with two 300 kW_T chillers that operate with a COP of 6. Operation will be staged so that the second chiller operates only when the cooling load requires it. The EMCS will alternate lead-lag operation to equalize run-time on each chiller.
4. Each fan in the 2-cell induced-draft cooling tower will be converted to 2-speed operation by adding a pony motor.
5. The chilled water loop will be converted from primary-only to primary/secondary operation. Three-way valves in the air handlers will be converted to two-way operation. A VSD on the secondary loop pump will modulate the pump motor to maintain a constant discharge pressure.
6. Fluorescent lighting will be upgraded to T-8 lamps with electronic ballasts. Occupancy sensor will be installed in conference rooms and other appropriate areas.
7. The increase in the number of computers used in the last 5 years is causing power-quality problems within the building. Excessive odd harmonics on the neutral lines is causing local distribution transformers to overheat, indicating a decrease in efficiency. Capacitors will not correct this problem, so the transformers will be replaced with high-efficiency models that are capable of handling distorted waveforms without incurring excessive losses.

Commercial Office Space (new construction): Two competing designs for a new office building are being selected. The firm funding the building construction plans to lease the space to small businesses. Reduced utility costs could be used as a selling feature to justify the potentially higher lease rates for the second building. Although the tenant will pay the utility bills, the investment firm is interested in tracking the savings so that they know whether their claims of reduce utility costs are valid. The first building is of conventional American style (box of glass) and construction and includes T-8 lamps with electronic ballasts, a centrifugal chiller (R-134a), and single-pane clear windows (fixed). The competing design offers the same useable space but costs slightly more than the typical design. It includes an open atrium, exterior shades (shelves) to reduce direct sunlight while allowing indirect lighting, T-8 lamps with dimming ballasts that dim in response to available daylight, and operable windows for natural ventilation. A chiller plant with a thermal energy storage system will provide conditioned air when natural ventilation is inadequate to provide cooling. The second building is promoted as being sufficiently energy-efficient that total operating costs (capital repayment + energy expenses) will ultimately be lower than the first building.

Office Lighting: Lighting will be upgraded by replacing magnetic ballasts with electronic ballasts and installing T8 lamps. The electricity use is recorded by the Electricity Board in 6 different meters. Ceiling fan loads are also connected to the same meters. Electrical savings to the tune of 25 to 30% are expected. The usage pattern varies depending on the natural light and the season. Presently, about 15% of the fixtures have failed and are not working.

Residential Sector

Utility Market Transformation Program: A utility wants to reduce peak demand by encouraging the use of compact fluorescent lamps in the residential sector. They propose mailing one compact fluorescent lamp to a select group of customers along with coupons for 30% off additional compact fluorescent lamps (up to 4) at local stores.

Government Water Efficiency Standards: Proposed legislation would ban the sales or installation of toilets using more than 6 L per flush and showerheads using more than 12 L/min. Although no one is 'funding' this project, the Ministry wants to understand how this will affect water use over a 20 year span. This will assist planning for water development, water infrastructure, and wastewater treatment plants.

I P M V P

Presentation develop by:

Satish Kumar

of the

Lawrence Berkeley National Laboratory

(and edited by Mark Stetz of Schiller Associates)

IPMVP World Wide Web site: http://www.ipmvp.org

IPMVP - Objectives

- **Reduce transaction costs by providing international, industry consensus approach and methodologies**
- **Replace multiple, incompatible protocols with single consensus approach**
- **Increase reliability and level of savings**
- **Reduce financing costs by providing project M&V standardization, thereby allowing project bundling and pooled project financing**
- **Provide a way to update the standard for future needs**

IPMVP - Scope

- Addressing the M&V needs of participants in energy and water efficiency projects
- Defining the role of verification in third-party financed efficiency projects
- Providing industry consensus options, with varying levels of accuracy and cost, for verifying:
  - Baseline and project installations conditions
  - Long-term energy and water savings performance
- Providing techniques for calculating "whole-facility" savings, individual technology savings and stipulated savings
- Defining procedures which are:
  - Consistently applicable to similar projects
  - Internationally accepted, impartial and reliable

IPMVP - Target Audience

- Facility Energy Managers, particularly public buildings
- ESCOs (Energy Service Companies)
- WASCOs (Water Service Companies)
- Development Banks
- Finance Firms
- Utility DSM Managers
- Building Managers
- State and Municipalities

Uses of M&V

- Determine energy savings
- Integrated with commissioning can provide feedback on performance of ECMs
- Long term feedback for on-going fine-tuning of ECMs
- Documentation for evaluating (and justifying) future ECMs
- Enhances Indoor Environmental Quality
- Basis for documenting emissions reductions and securing credits

IPMVP as Basis for International CO_2 Trading Regime

- Allow credits to accrue at the project level
- Industry consensus
- Measurement as cost savings, not added cost
- Standardization allows bundling

M&V Efforts in U.S.

1970's	Case by case measurement plans
1983	IEA's "Guiding Principles for Measurement"
1985	First utility sponsored large scale programs
1988	New Jersey Utilities M&V plan
1988	First NAESCO M&V plan
1992	California CPUC M&V Protocol
1992	New Jersey Standard Offer Protocol
1993	NAESCO M&V ver 1.3
1994	PG&E PowerSaving Partners "Blue Book"
1995	EPA Conservation Verification Protocols
1995	LoanSTAR (Texas) Protocols
1996	North American Energy Measurement & Verification Protocol
1996	FEMP application
1997	International Performance Measurement & Verification Protocol
2000	IPMVP 2000, FEMP 2.2, ASHRAE 14-P (draft)

M & V Methods

	IPMVP	FEMP	ASHRAE 14-P
Retrofit Isolation	A	A	-
Retrofit Isolation w/ continuous metering	B	B	Retrofit Isolation
Utility Bill Analysis	C	C	Whole building metered approach
Building Simulation	D	D	Whole building calibrated simulation

M&V Options in the IPMVP

- **Option A: Stipulated Baseline and Performance**
  - Verified equipment performance potential
- **Option B: Stipulated Baseline, Verified Performance**
  - Estimating tool calibrated with end-use data

Measure

- **Option C: Comparison of similar buildings with and without ECMs using whole building data (hourly or monthly)**
- **Option D: Stipulated Baseline, Verified performance**
  - Estimating tool calibrated with whole building data

Building

Option A

- **Properly defined baseline conditions**
- **Projects where verifying the *potential* to generate savings is the major concern (or the risk to be mitigated)**
- **Actual energy or cost savings are not verified**
- **They are *predicted* using engineering or statistical methods**
  - Using historical data for operational factors (occupancy schedule etc.)
  - May use spot or short-term (but not long-term) measured data to estimate performance factors
- **Option A includes primarily verification activities such as physical assessment of equipment changes**

Option B

- Properly defined baseline conditions
- Projects where actual savings (energy and cost) during contract need to be determined, based on end-use
- Involves long-term measurements for both *Performance* and *Operational* factors
- A "Retrofit Isolation" method
- M&V can be performed at the equipment or system level and goes on for the term of the project
- Same procedures as Option A plus measurement of pre- and post-installation energy use

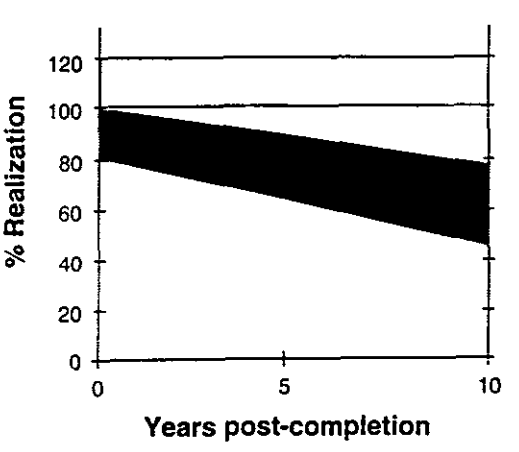
Option C

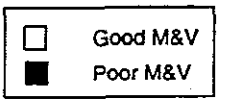
- Properly defined baseline conditions
- Projects where actual savings (energy and cost) during contract need to be determined, based on end-use
- Utility whole-facility meter analysis calibrated with utility billing data
- Savings are determined by "whole facility"
- Same procedures as Option A plus measurement of pre- and post-installation energy use

Option D

- Use of a calibrated simulation tool to estimate "before" and "after" energy use
- Simulation of whole building or just end use
- Building simulation model (e.g. DOE-2), or a spreadsheet, or VSD estimating program, etc.
- Calibration is done by:
  - Linking simulation inputs to actual operating data, and
  - Comparing the results with end-use or whole building data
- Used for new buildings and complex existing building systems

Project Comparison





- Three key components
  - Initial savings level
  - Persistence of savings
  - Variability

Useful Web Sites

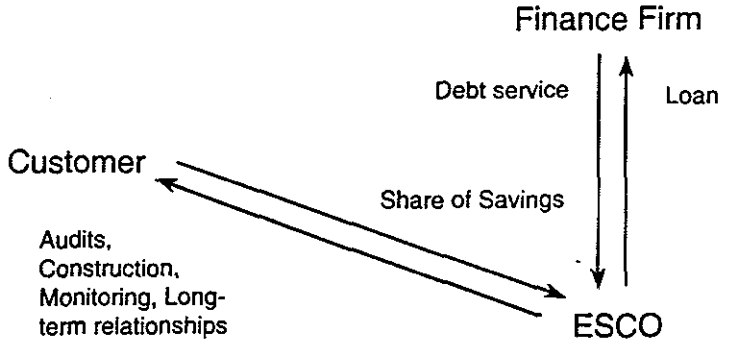
Industry Protocols

- IPMVP www.ipmvp.org
- FEMP www.eren.doe.gov/femp/financing/measguide.html
- LBNL ateam.lbl.gov/mv/
- ASHRAE www.ashrae.org

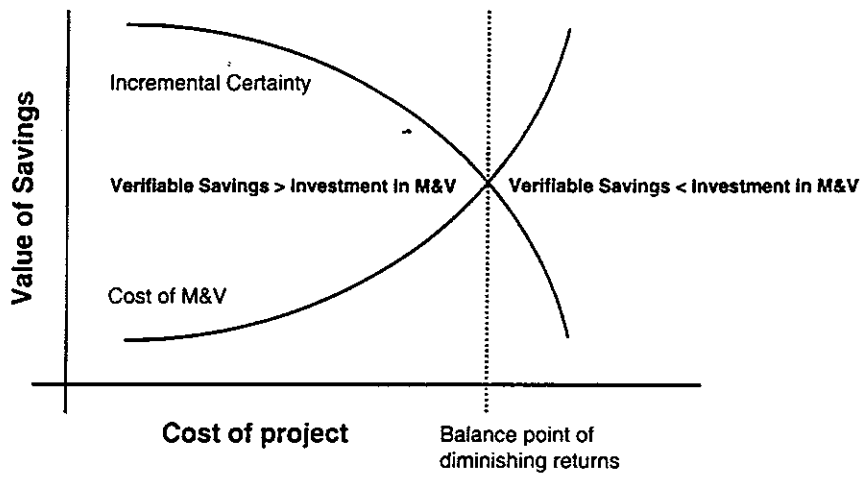
Utility Protocols

- Standard Performance Contract (CA)
  - **PG&E** **www.pge.com/spc**
  - **SCE** **www.scespc.com**
  - **SDGE** **www.sdge.com/spc/bus/**

Full Recourse Project Financing



Trade-off Between M&V and Cost



Common Energy Cost Savings Measure

- Lighting Improvements
- Electrical Motors and Drives
- Boiler Improvements
- Chiller Improvements
- Improving Control Strategies
  - Building Automation Systems (BAS)
  - Energy Management Control Systems (EMCS)
  - Utility Monitoring and Control Systems (UMCS)
- Heating Ventilating and Air Conditioning
- Building Envelope Modifications
- Water and Sewer Conservation Systems
- Renewable Energy Systems

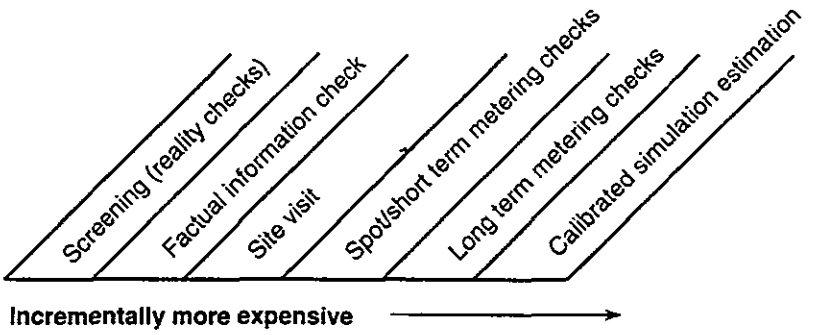
Overview of M&V Options - 1

- Option A (1-5% of project construction cost)
  - Properly defined baseline conditions
  - Focuses on physical assessment of equipment changes
  - Reliance on historical data for *operational* factors (occupancy schedule etc.)
  - Use of spot or short-term measured data to estimate *performance* factors
- Option B (3-10% of project construction cost)
  - Properly defined baseline conditions
  - Verifying energy and cost data obtained during term of agreement
  - Use of long-term or continuously measured data for both *performance* and *operational* factors
  - M&V can be performed at the equipment or system level and goes on for the term of the project

Overview of M&V Options - 2

- Option C (1-10% of project construction cost)
  - Properly defined baseline conditions
  - Savings are determined at the *"whole-building"* level
  - Reliance on a combination of utility billing analysis and sub-metered data (for calculations.
- Option D (3-10% of project construction cost)
  - Properly defined baseline conditions
  - Savings are determined through *simulation* of individual system or "whole-building"
  - Simulation model is *calibrated* with hourly or monthly utility billing data and/or end-use metering
  - Used for new buildings and complex existing building systems

Layers of Measurement & Verification



- Option A - End use, measured capacity, stipulated consumption
- Option B - End use, measured capacity, stipulated consumption
- Option C - Whole building or main meter approach
- Option D - Calibrated simulation approach

How to Get a Copy of IPMVP

- For hard copies, call Energy Efficiency and Renewable Energy Clearing House (takes 2-4 days to receive a copy)
  - 1-800-DOE-EREC
- Electronic Download (in MS Word and Acrobat)
  - www.ipmvp.org/download.html
- For miscellaneous information
  - s_kumar@lbl.gov
  - 1-202-484-0884 x110

How to Specify Compliance

- State the document to be referenced
- State which option and method will be used
- Indicate who will conduct the M&V
- Define the details of how calculations will be made
- Specify the metering
- Define key assumptions
- Define the level of accuracy
- Define quality assurance methods
- Define reporting contents and schedule

IPMVP Uses - 1

In the United States

- ESCO industry standard
- Federal buildings through FEMP
- State-wide adoption
  - California
  - Florida
  - Iowa
  - New York
- Basis for innovative, large scale financing initiatives
  - NYSERDA
- To achieve and demonstrate state compliance with Federal Clean Air Act Requirements under State Implementation Plans (SIPs)
  - New Jersey (preliminary)

IPMVP Uses - 2

Currently (or beginning to be) used

- by Multi-lateral Development Banks as a key design element in large scale energy efficiency loans
  - World Bank
  - International Finance Corporation
  - Inter-American Development Bank (IDB)
  - European Bank for Reconstruction & Development (EBRD)
- for determining reduction of greenhouse gases
  - Inter-Governmental Panel for Climate Change (IPCC)
  - Global Environment Facility

IPMVP - International Participation

Countries with National Participating Organizations

- Brazil
- Bulgaria
- Canada
- China
- Czech Republic
- India
- Japan
- South Korea
- Mexico
- Nepal
- Poland
- Russia
- Ukraine
- United Kingdom
- United States