

MANAGEMENT, MEASUREMENT & VERIFICATION

of Performance Contracting

James P. Waltz, P.E.

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Dedication and Acknowledgments

This book is dedicated in memory of my father Bob, a genuine American hero and veteran of Bari, from whom I received the gifts of patience and service, in memory of my mother, Lenore, from whom I received the gifts of curiosity and originality, and to my family, Mary Jane, Mike, Julie and Alice, who have shared the toilsome trail along the way.

This book is also dedicated in reverent honor of my band of brothers who have braved harm's way in the service of their country and made their shatteringly profound installment on the price of peace—especially those who also wore that raucous eagle blazon upon their sleeve.

I would also like to thank the entire staff at ERA who helped tremendously in supporting this effort, along with my contributing authors, Steve Kromer, John Avina, Lou Ronsivalli, Marty Mozzo and Kevin Fraser, and my faithful editors Michael Waltz, Bill Payne and Linda Hutchings.

Finally, this book is dedicated to the “guys” who were there at the beginning of the energy services industry, providing the inspiration and “keeping the faith” in pursuing a radical new way of delivering services to building owners, including:

- Chet Lyons, Jim Harven, Richard Overgaard and Tom Staton (CommAir Mechanical Services)
- Dick Neubauer, Dave Carey, Lou Ronsivalli, Tom Monroe (with an “e”), Bob Batch, Jim Hoverson, Craig Stensen, Tonnie Baser, Chris Kantlon and Bob Dixon (Johnson Controls)
- Ted Swanson (San Francisco Chronicle and Examiner)

and many others I'm embarrassed to say that I've forgotten over the years.

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Preface

This book is not for the faint of heart. Indeed, we considered changing the title as the book came to completion because myself and my contributing authors are of a common ilk in that we all tend to “call ‘em as we see ‘em,” sometimes to the consternation of assorted bystanders.

As a result, this is a book that will give the untutored a rare insight into the world of performance contracting, indeed, insights that at times may be a bit unsettling—literally, **what you always wanted to know, but were (truthfully) afraid to ask.**

I believe that readers will detect this as a sort of “theme” throughout the book. While my fellow authors may not completely agree with the manner of expression of the reflections that follow below, they would (I believe) support that they are fairly held.

One of my personal concerns over the years is that the business proposition of performance contracting is so extremely compelling that it sort of invites unscrupulous behavior on the part of those entering the marketplace without the dedication to the ethic of conservation. I tend to refer to this as the “dark side” of performance contracting. It will be explored in some detail throughout the book.

We have come to know this “end” of the spectrum quite well over the years due to our background as ex-design/build folks who, for the first ten years of the company’s existence, served performance contractors from the inside. Among other things, we were called in not infrequently to “clean up” our ESCo client’s problem projects. In truth, we were doing program evaluation and measurement and verification a decade or more before most of the industry realized it even existed, including developing and copyrighting one of the first energy accounting software programs in the very early 1980’s, the *Energy Accounting Report System*. Its vestiges can be seen in software the likes of *Metrix*, among others.

While it wasn’t the path we intended to travel, at **ERA** we have become quite accomplished as forensic engineers in assisting those entangled in a troubled performance contract. For example, just a year ago we assisted one client in settling a \$10,000,000 claim—the plaintiff walked away without a penny 60 days following our deposition. We

think that's pretty powerful.

We find it disheartening that there is a need of the services of a "cleaner" like ourselves, since we helped to create the industry in the early 1980's based on the concept of creating a win-win relationship between the Owner and ESCo with the parties mutualizing their motives to create such a "marriage." I believe that all the authors contributing to this book still see that performance contracting is of this nature when it is properly done. Perhaps the most disturbing was learning of and reading about the fiasco in the State of Arizona as documented in the Report to the Arizona Legislature By the Auditor General, entitled "Energy-Saving Devices and Services Budgeted for By School Districts." The Auditor General stated (and documented) two fairly earth-shaking conclusions:

1. "Districts" most likely did not realize budgeted savings because of their reliance on aggressive contractor savings projections."
2. "District procurement decisions" are heavily influenced by contractor marketing strategies. These strategies include the representation that projects will pay for themselves, the presentation of proposals containing all-inclusive cost estimates (i.e., bundling) and the promotion of costly service contracts."

Among the recommendations of the Auditor General was to revise the laws authorizing the use of performance contracting in the state by public agencies. We considered it a dismal state of affairs for the industry that business practices had sunk so low on such a broad scale so as to create a state-wide scandal such as this.

The Arizona auditor General's report is unique in the marketplace because there is a dramatically powerful bias for not "airing dirty laundry" in this business. No one, and perhaps especially the Owner's project manager, wants it to be widely known that a performance contract is not performing. It's a "tricky" rather than a "no-brainer" business this performance contracting, and it is not always clear to the participants how tricky it is—until it is too late. See Chapter 4 for more discussion.

Our business theme in the performance contracting arena has therefore been, for quite some time, to raise the level of play in the industry so that the good guys could hold their heads up and do good business

without having to resorting to unsavory practices just to compete. And the problems exist on both sides of the table (ESCo and Owner), not just one—as discussed in Chapter 3.

A couple of current trends in the marketplace continue to disturb us, however.

One is the movement in the wrong direction—towards deregulation and the commoditization of the facility-services side of the business. One has only to read the San Francisco Chronicle to learn of a major East Coast Utility which has “impaled themselves on the native spears” in attempting to create an unregulated performance contracting subsidiary. The nominal value of the lawsuit is over \$90,000,000 at last report and warrants for the arrest of certain Owner’s staff members and certain of the ESCo’s staff have been issued by the San Francisco District Attorneys Office. While it is well intended, the U.S.-wide Super-ESPC program has elements in it that are of frighteningly similar potential (and have already been reported by on-site project managers to at times produce very unsatisfactory results). Retrofitting buildings is a lot more like micro-surgery than it is delivering pizzas, and vendors attempting to more or less deliver energy retrofit “by the truckload” are missing the essence of what this business is all about (again, as discussed in Chapter 3) and no amount of “forward-thinking” trends are going to change the essential nature and requirements of the business—no matter how many “Dilbert” managers think so.

Another is the conventional wisdom that the new world of Measurement & Verification represents the first line of defense in managing a performance contract. This notion is seriously flawed, as is detailed in Chapter 4. Indeed, it is our long-considered opinion, that a well-managed energy retrofit program doesn’t really need a guarantee, and is why the model performance contracting documents we developed for the State of California embody a very short performance-demonstration period.

We trust that readers will value the down-to-earth, and practical “bent” which this book possesses, as well as its moments of humor and candor. We certainly don’t think you’ll find it anywhere else in any significant quantity.

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Contributors

STEVE KROMER is a co-founder and principal of Teton Energy Partners. He has spent the past twenty years in the field of energy efficiency where he has focused on energy measurement (M&V), energy information and risk management. Prior to starting Teton Energy, Mr. Kromer worked for the National Center for Appropriate Technology, the Lawrence Berkeley National Laboratory and most recently for Enron Energy Services. He is the a member of the board and executive committee of the International Performance Measurement and Verification Protocol (IPMVP).

An engaging speaker, Mr. Kromer has taught numerous performance contracting seminars for the Association of Energy Engineers (AEE) and conducted numerous measurement & verification seminars for the DOE in support of the Federal Energy Management Program (FEMP).

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Abraxas Energy Consulting sells and supports utility bill tracking, energy analysis and M&V software, including Metrix™, Utility Manager™ and Stark Essentials™. The company also provides engineering services such as bill tracking, energy audits, third-party M&V, and re-

lated customized software applications.

Mr. Avina has a MS in mechanical engineering from the University of Wisconsin-Madison, where he interned at the Solar Energy Lab. He is a member of the Association of Energy Engineers (AEE) and a Certified Energy Manager (CEM).

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He has been working in the energy and facilities management industries for over 25 years, and began as a project engineer developing "pay-from-savings" projects retrofitting constant-volume central air systems to VAV in 1977.

During a 12-year period at Johnson Controls, Mr. Ronsivalli developed and managed facilities operations contracts, and developed energy services projects, culminating with a branch manager's position in Providence, RI, in 1991. It was with Johnson that Mr. Ronsivalli and David S. Carey co-developed the ground-breaking Massachusetts Government Center Shared Savings project (at the Saltonstall & McCormack building complex) in 1986, widely recognized as the region's most significant energy services project of the 1980s.

Subsequently, Mr. Ronsivalli has held a variety of leadership positions in the Northeast with highly visible players such as York International, Xenergy, and Trigen. He later spent two years with the internet applications service provider, True Advantage, and acquired an excellent understanding of integrating e-commerce strategies with traditional business models.

He has also taught a variety of college level courses including business management, mathematics and computer applications. He has had recent articles published by Hart's Energy Markets and the Association of Energy Engineers' *Cogeneration and Competitive Power Journal*.

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nies. Prior to starting M&A Associates, Inc., Mr. Mozzo worked for Energy Performance Services, Inc., and KENETECH Energy Management, Inc., both nationally prominent energy service companies. Prior to that, Mr. Mozzo worked for 17 years at American Standard, Inc., in a number of positions including corporate director of energy management.

Mr. Mozzo has been very active in the Association of Energy Engineers. He is currently past president of AEE, having served as president during 1999. He currently serves as chairman of two of AEE's certification boards, the Certified Lighting Efficiency Professional (CLEP) and the Certified GeoExchange Designer Boards. He is a senior charter member of AEE, was Region I vice president (national) for two years, was executive vice president, and was a board of director member for the New Jersey chapter for several years. Mr. Mozzo was elected into the AEE Energy Managers Hall of Fame in 1995.

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Prior to joining PG&E Energy Services as a national director Mr. Fraser served as an international corporate real estate consultant for Ernst & Young Kenneth Leventhal. He has held facilities and administration management responsibilities for David Rockefeller, Prudential Insurance, John Portman & Associates, Pacific Park Plaza and Wind River Systems.

Mr. Fraser is credited with writing and releasing the nation's first true open market RFP for deregulated electricity. He has led or participated in energy commodity and related services totaling billions of dollars, including the largest single energy services agreement in history. His experience includes representing the end user, intermediary, independent third-party and supplier.

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Chapter 1

Introduction

WHAT THIS BOOK IS ABOUT

After consulting in the performance contracting field for nearly twenty years, we have come to the realization that even after all of this time there's really more ignorance than knowledge about performance contracting in the marketplace. As observed by an attendee at one of our performance contracting seminars, the level of knowledge and performance contracting acumen has perhaps grown on the ESCO side of the table, but a counterbalancing or complementing level of knowledge and facility has not developed on the owner's side of the table. With the "playing field" so tilted, it seems to lead to mismatches and less-than-desirable results in the business of performance contracting.

The purpose of this book, then, is twofold:

- The first purpose is to inform readers of the nature performance contracting and appropriate techniques for successfully managing performance contracts.
- Secondly, our purpose is to inform readers regarding the various available techniques for measuring and verifying the results of performance contracting.

As we explain to our seminar attendees, and which will be true with this book as well, our point of view is somewhat biased toward the owner's side of the table. We do not see this as a particular problem as we believe, rather strongly, that a proper performance contract provides for the owner and the ESCo to form a team and to mutualize their motives in the process. As a result, we believe that what is good for the owner is also good for the ESCo, and that there really should be no conflict between the two parties in a proper performance contract.

HISTORY OF PERFORMANCE CONTRACTING

One of the more frustrating aspects of the performance contracting business is the fact that it seems to be a perpetually adolescent industry. Because of the waxing and waning in the prices of energy and the general health of the economy both in the U.S. and worldwide, performance contracting has also waxed and waned and, in a way, has been rediscovered a couple of times since its original inception.

Since it occurred almost thirty years ago, energy engineers and building managers much less than the age of fifty will have difficulty remembering the Arab Oil Embargo of 1973. This was a rather dramatic event whereby OPEC (the Organization of Petroleum Exporting Countries) basically closed the valve on the supply of oil to the world. This was done almost purely in an effort to control the world supply of oil and drive up the market value of oil as a commodity. It was, indeed, very effective, as those of us who sat in long lines at gas stations during that era will vividly remember. Interestingly, the laws of supply and demand were still in full force and effect, if slow to respond. The United States, in particular, was very slow to respond to the forces in the marketplace. This was because, in many ways, high levels of energy use had essentially been institutionalized within the culture and various infrastructure systems in our economy, including transportation and buildings.

This institutionalization of high energy use was, perhaps, most dramatically demonstrated when President Carter put into effect the Emergency Building Temperature Restrictions (EBTR) of 1978. In a nutshell, these regulations required that every building in the United States above a certain size take certain actions to save energy on what was considered to be an "emergency" basis. This included setting thermostats to 78 degrees in the summertime and 68 degrees in the wintertime. In addition every building covered by the regulations had to post a certificate signed by the building manager at the entry of the building to demonstrate their compliance with the regulations. Now it seems, unfortunately, that in that era a certain type of heating ventilating and air-conditioning system (HVAC) was considered to be the "Cadillac" of HVAC systems. That type of system is known as terminal reheat. Because a terminal reheat system provides a constant supply of cold air throughout the building which is then reheated just before delivery to the occupied space, raising the thermostat in the summer time to 78 degrees (as opposed to, say, 72 or 74 degrees) causes the reheat coils to

do more heating, which then raises the space temperature, which in turn raises the return air temperature, which then causes the cooling coil at the air handling unit to have to do more work to cool down the over heated return air—all of which results in a twenty to thirty percent increase in the heating and cooling energy required to operate these systems! Needless to say, the EBTR was not effective in reducing the energy consumption in a very large number of large buildings throughout the United States. Thus was high energy use very effectively institutionalized in the very infrastructure of the buildings.

By 1980 the Carnegie Mellon Institute (in the person of Roger Sant) was investigating a new “least cost” approach to providing “energy services.” The results of this endeavor were reported upon in the May-June issue of the Harvard Business Review, and represents a landmark document, marking the beginning of the “energy services” or “performance contracting” industry. Interestingly, the providing of energy services instead of energy was exactly what Thomas Edison intended when he originally set out to electrify the world. Unfortunately, Tom was unable to come up with a scheme to measure a somewhat intangible value such as illumination on a work surface, and therefore defaulted to simply measuring the power being shipped down the electrical pipeline. Indeed, the concept of providing energy services as opposed to energy was a very novel concept in 1980. The whole idea focused around the concept of providing the end result rather than just the input feedstock, accompanied by the idea that this could be a self perpetuating activity as the cost of the technical improvements could be paid out of the reduction of the operating costs of the facility. Radical thinking indeed!

The Department of Energy got into the act as well in the 1980's by undertaking program development activities in the field of energy services. Among other things, the Department of Energy engaged a fellow by the name of Martin Klepper (who then worked for a firm named Lane & Edson, P.C.) to develop a model energy services agreement. To this day many of the more mature ESCo's still use contract language that was first crafted as part of the DOE's model energy services agreement that Marty developed.

In 1983 the National Association of Energy Service Companies (NAESCO) was founded. At about this time, enabling legislation was passed, which included California's AB 1942, otherwise known as the Davis Act. This Legislation authorized local governmental agencies (school districts, counties, cities, etc.) to enter into sole-source con-

tracts on the best available terms to do energy services work. Curiously, while this legislation authorized this practice across the state, it specifically prohibited State agencies from employing the same approach to providing energy services. This was not to be corrected for approximately fifteen years until AB 1890 (the Electric Restructuring Act) was passed, which specifically authorized state agencies to employ energy services.

In 1986 OPEC essentially collapsed, oil prices fell through the bottom, an awful lot of people in Texas filed bankruptcy (including John Connelly), and Sheik Yamani of Saudi Arabia lost his job as Minister of Oil for Saudi Arabia. Following this event, of course, many of the firms who boldly had entered the energy services field (including our own firm) found themselves with not a whole lot of work to do.

Around 1990 the various public utilities commissions and utility companies around the country discovered the concept of demand side management (DSM)! Conferences were held across the country on a regular basis and whole new professional associations were formed, including the Association of Demand Side Management Professionals. Unfortunately, as both the PUC's and the various utilities had virtually no background or insight into the actual end uses of energy in buildings, these programs were very frequently poorly conceived and also very frequently implemented in very academic fashions. Perhaps not surprisingly, within a few short years (approximately 1995) "DSM" was declared a bad word and virtually disappeared from the vernacular overnight, even to the extend of the Association of Demand Side Management Professionals changing their name to the Association of Energy Services Professionals.

Around 1996 numerous utilities around the country began investigate and implement the creation of new unregulated performance contracting subsidiaries. We have not taken a count lately, but we believe that virtually every utility in the United States has formed one or more (due to start-ups and subsequent failures) unregulated subsidiaries in the late 1990's.

Just out of curiosity, we examined our records and identified the players who were actively engaged (not just fooling around) in the energy services business in 1983, as follows:

- AirCon Energy (small design build/contractor in Sacramento, California—later sold to Linford Service, now part of Encompass)

- Amtech Energy (a subsidiary of ABMI, now defunct)
- CES/WAY (originally known as Commercial Energy Systems, later merged with Way Engineering, now a subsidiary of Sempra)
- Citizens Energy (later Citizens Conservation Corporation, then EUA/Citizens Conservation Services, now part of Ameresco)
- Citizens Heat and Power (cogeneration developer, started by Citizens Energy, known as EUA Cogenix when purchased by Eastern Utilities, later sold to Alliant Energy)
- Co-Energy Group (a financial broker now turned turnkey contractor)
- CSL (the originator of the concept “Shared Savings,” now defunct)
- Driver Engineering (now defunct)
- Energy Masters (later a subsidiary of Cenerprise, who then changed their name to Energy Masters, then acquired by Northern States Power, then subsumed into Planergy, when Northern States Power and New Century Energy Merged to become Xcel Energy)
- Hospital Efficiency Corporation (later known as HEC Energy Services and HEC Inc., now known as Select Energy Services, owned by Northeast Utilities)
- Johnson Controls
- Natkin Energy (acquired by ServiceMaster, since sold to Texas Utilities)
- Nees Energy Inc. (founded by New England Electric System, sold and later known as Northeast Energy Services, now known as Noresco)
- National Energy Management Institute (NEMI, a SMWIA and SMACNA joint venture, now defunct)

- Onsite Energy (a cogeneration developer, now a performance contractor—had joint ventures EUA/Onsite and Onsite Sycom)
- Time Energy (went from being the “darlings of Wall Street” following their IPO to being out of business ninety days later when the IRS declared their tax credits illegal!)
- Viron (acquired by York International, now owned by CMS Energy—but sale plans announced in mid-2002 by CMS)

So, as we can see, the performance contracting industry, once known as energy services, is perhaps on its third “life cycle,” having possessed three different names to date and having been discovered three times. Such has been the tumultuous history of this “industry.”

Those readers interested in a more scholarly treatise on the history of the energy services business are referred to a document published by The World Bank in 1999, entitled “The Energy Service Industry.”

Chapter 2

What Is

A Performance Contract?

When originally conceived more than 20 years ago, the concept of performance contracting, or energy services as it was known then, was a truly unique offering because it assembled in a single package a unique combination of services which constituted a deal that was and is truly compelling.

THE ESSENCE OF THE DEAL

While opinions at times will vary, as it is commonly understood and practiced, a performance contract generally includes the following elements:

- The ESCo figures out what is wrong with the building, or, conversely, identifies the opportunities to improve the facility and its operation.
- The ESCo engineers the fix. That is, the ESCo handles all of the technical details relating to the design and layout, and plans for the installation various retrofit measures.
- The ESCo installs the fix. That is, the ESCo acts a turnkey general contractor, handling installation retrofit measures themselves or subcontracting all of the work for the various retrofit measures.
- The ESCo guarantees that the project will work. That is, the ESCo assures the building owner that their total costs go down. In essence the debt service is paid out of the results of the project which are reduced operating costs for the building.

In other words, performance contracting looks an awful lot like a “guaranteed free lunch!”

But building owners who have rapidly concluded that performance contracting is the greatest thing since sliced bread may suddenly have misgivings when hearing performance contracting described that way.

Another critically important characteristic of performance contracting, but which is overlooked or misunderstood by many buyers, especially public agencies, is that performance contracting is a design-build process. In this design-build process, the vendor exercises a great deal of control over the project implementation—far greater control than in the more traditional design-bid process. In addition, the vendor does most of the work and possesses most of the information regarding the project (meaning that the owner has relatively little information). We have frequently observed, in our projects over the last 20 years, that we almost always end up better understanding an owner’s building and how it is operated than does the owner’s in-house staff. In fact, this phenomenon has at times been the “clincher” in selling a performance contract to the building owner. Because of this design-build nature of performance contracting, and the fact that performance contracts frequently have a very broad scope (covering an entire facility and the majority of its infrastructure systems), the relationship between the parties and the process that is used to create and implement a project assumes new and much greater importance.

AT THE BEST...

When performance contracting is done well it provides the owner with a package of services and benefits that cannot be equaled by any other means, including:

- Funding and Assurance
- Project Management
- Engineering, including both investigative and design services
- Installation and Contracting
- Monitoring and Maintenance

Faced with a myriad of manufacturers, vendors, sales reps, engineers, brokers, service companies, contractors, consultants and others,

each offering some piece or even pieces of the pie, it is not surprising that building owners 20 years ago, and even today, often find that a performance contract is the only vehicle by with they can make reasonably rapid progress in correcting facility infrastructure deficiencies. There is another side to the coin, however.

AT THE WORST...

The potential downside of a “guaranteed free lunch” is that an untutored building owner can be lulled into a sense of complacency, making them “ripe” to be taken advantage of by the unscrupulous ESCo. Based on the expert testimony and “cleaner” (visualize the movie “Pulp Fiction”) work that we have done in the last 20 years, we have observed that, at the worst, a performance contract can bring an owner:

- Funding
- Pseudo-Project-Management, (a false appearance that the project is being adequately managed)
- Bogus Engineering (meaning that no one has really planned the project in any detail)
- Lots and Lots of Subcontractors (meaning that the performance contractor is actually only in a brokerage role)
- Bogus Monitoring (meaning that measurement and verification reports are generated out of thin air, rather than from hard data)
- No Ongoing Maintenance (Indeed, we have observed at times that the service contract part of a project is being used to attempt to finish the original installation, instead of providing ongoing maintenance.)

It is a sorry situation indeed when this occurs in a performance contract. Unfortunately, those building owners that are in the most need of performance contracting, e.g. school districts and other public agencies, are also the ones most likely to be misled and taken advantage of. This is a “perfect fit,” as the saying goes, though not in a positive way.

WHO ARE THE PLAYERS?

As time has shown over the last 20 years, the players in the performance contracting business come and go, associate and disassociate, change their names and evolve over time in rather interesting ways. An owner considering hiring a performance contractor, as well as a performance contractor presenting their qualifications to a prospective client, need to think about the characteristics that a performance contractor may possess or appear to possess.

Table 2.1 presents a very simplistic “model” thumbnail sketch of the principal characteristics of four rather broad groupings of performance contractors, or ESCo’s. While this model is imperfect and while it was developed quite a few years ago, it still fulfills a useful function in that it provides a framework within which we can evaluate the characteristics of an ESCo. We have identified four general groupings, including a Manufacturer, a Broker, a Contractor, and a Utility. The truth is, most of the companies involved in performance contracting probably fit in more than one of these categories. However, their past history and/or their current configuration will generally tend to fall mostly into one of these four categories, particularly if you consider that the category of Utility might also cover a modern term known as ESP, or Energy Service Provider. With the deregulation of the utility industry, what we used to know as a Utility has taken on a new shape and form and is really hard to define these days. Since no one ESCo will probably fit perfectly into any of the categories in Table 2.1 exactly, and as the characteristics for a given “model” ESCo are significantly generalized and simplified, we will not attempt to explain or amplify the table, but only offer it as a model or matrix that may be useful when considering the relative strengths and weaknesses of ESCo’s.

DO YOU NEED AN ESCO?

Depending upon whom you speak to and when, performance contracting is considered so compelling that it is thought of at times as a “no-brainer.” At the same time, many building owners, after considering what a performance contract actually brings to their table, find themselves questioning whether performance contracting is such a good thing after all. This is a good frame of mind for most building owners to be in.

Table 2-1. ESCO Characteristics

Characteristic	ESCO “Model”			
	Manufacturer	Broker	Contractor	Utility
Geographic Scope	National	National or Regional	Mostly Regional	National or Regional
Principal Focus	Installation & Service	Placing Funds	Installation & Service	Diversifying into un-regulated business
In-house Engineering	Moderate to Substantial	Generally Nil	Moderate to Substantial	Nil to Moderate
In-house Installation	Moderate to Substantial	Generally Nil	Moderate to Substantial	Generally Nil
On-going Service & Monitoring	Generally In-house	Generally Sub-contracted	Generally In-house	Generally Sub-contracted

As the business schools teach, every decision is made “at the margin.” That is, everything that has happened in the past is in the past, and every decision is made, or should be made, on a “going forward” basis—meaning that the next dollar that is spent should be considered as though it is the first dollar being spent. An astute building owner will not just assume that a performance contract is the right answer but will also consider the possibility of using more conventional means.

Performance contracting brings a unique package of service and products to the table. However:

- Independent financial services are available, through which a financially solvent building owner with a worthy project can obtain third party financing directly.
- Independent project management services are available from a myriad of consulting firms.

- Independent technical services are also available from engineering consulting firms.
- Independent monitoring and verification services are also now available. Some firms are now specializing in this field of activity.

The bottom line for a performance-contracting-like project, e.g. an integrated comprehensive energy conservation and infrastructure renewal project, is that the project can be done without a performance contractor as long as the building owner realizes that he must provide program management to oversee the entire process.

Chapter 3

Picking a Performance Contractor

As we have seen it in our more than two decades of experience in the field, there are a few basic fundamentals that must be addressed if one is to do a performance contract successfully. In fact, as a matter of practice, as we advise our building-owner clients (hospitals, colleges, school districts, commercial office building owners, etc.) we recommend that a 7-step process be implemented, and that each step be managed and accomplished incrementally—as opposed to a more-or-less one-step process that is generally promoted by the industry. As you will read in the Preface, the insistence of a single-package “deal” on the part of certain ESCo’s has led to scandalous results at times, even though it is more or less embodied (or strongly implied) even in enabling legislation (such as the State of Nevada, NRS 338.1907, for example). Our 7-step process, each addressing an essential fundamental, includes the following:

- Pick the right ESCo (Request for Qualifications & selection).
- Do the homework (the investment grade audit).
- Negotiate a contract and arrange financing (the Energy Services Agreement).
- Project design (preparing construction documents)
- Project construction (“bricks and mortar” so to speak)
- Commissioning (otherwise known as “verification”)
- Post-retrofit monitoring (otherwise known as “measurement”)

The first fundamental will be addressed in this chapter and the rest of the fundamentals will be addressed in the following chapters.

RFQ'S VS. RFP'S?

One of the first questions owners should ask themselves is whether they intend to use a request for qualifications (RFQ) or a request for proposals (RFP). Requests for proposals are a fairly traditional methodology used particularly by public agencies in our experience. Unfortunately, when it comes to a performance contract, RFPs have some serious inherent drawbacks. No ESCo can afford “investment grade” feasibility studies on a speculative basis. A number of ESCo's have done such studies in the past, but, in truth, no ESCo can actually afford the significant cost of doing an investment grade audit in a high-risk sales situation. Owners who had deluded themselves into thinking that this can be done, just because they think it can, need to face reality. In order for an ESCo to actually do an investment grade audit on speculation, the competition must either be narrowed dramatically (say amongst a very small group of pre-approved performance contractors), or it must be deferred to later in the process. Because of this high risk to the ESCo (a lot of cost vs. a slim opportunity to succeed), it is not uncommon that a low-rigor “audit” is presented to prospective clients as though it is an investment-grade audit. Financial projections that are not backed up by investment-grade energy audits must, by their very nature, be highly speculative, or outright lies. The author apologizes for the strength of this language, but he has observed this scenario first-hand far too many times to not make this statement for the benefit of the untutored building owner considering performance contracting. This scenario is especially prevalent where the prospective buyer, the building owner, intends to use a financial projection as the ultimate decision criterion. (Those in doubt, please skip immediately to Chapter 9.) Guarantees, usually a key component of a performance contract, are unfortunately too often a ticket to get to meet the ESCo's legal staff. (Again, those readers in doubt should skip immediately to Chapter 9.) Given that an RFP prevents the homework being done and actively encourages speculation on the part of the ESCo's, building owners should ask themselves “Do you want to marry someone if you asked them to lie to you and they obliged you?” Again, we've seen this scenario play out again, and again, and again.

Finally, the question must also be asked: “Is your greed getting in the way?” As discussed in Chapter 9, one very large California county discovered that their greed caused the entire RFP and selection process to be biased towards achieving an impossible financial return for the county, setting the stage for a project that would ultimately fail and result in a major lawsuit and the ESCo going out of business.

So how can these potential pitfalls be avoided? The answer is, to use a request for qualifications (RFQ) in lieu of an RFP. RFQs work because:

- No speculative investment-grade feasibility study is required, which avoids putting the ESCo “between a rock and a hard place.”
- Only rough financial projections are required, and these projections would be based on a preliminary study for “ballparking” and “sampling” the ESCo’s technical approach. For example, in the case of a school district, a very small sampling of representative buildings would be identified to the prospective ESCo’s and they would be asked to do a very brief walk-through and look at the utility consumption data to provide a preliminary list of potentially attractive energy conservation measures, along with very rough cost and savings guesstimates.
- The focus of an RFQ is on the resources and the track record of the ESCo, i.e., their professional qualifications.
- To protect the owner, items like the ESCo’s “fees” (or markup, if you would call it that), the cost of money, and the definition of project cost, are agreed upon up front and can be incorporated in an open-book contract if the parties ultimately proceed.

Fundamentally, the RFQ process works well because it recognizes that the nature of performance contracting is more like the nature of professional services contracting than it is like the nature of competitive design-bid contracting. Figuring out what the opportunities for facility improvement are, and figuring out the best way to implement them, are far more valuable in this process than falsely (and foolishly) imagining that a side-by-side equivalent bid process is occurring.

KEY ELEMENTS OF THE RFQ PROCESS

The following should be integral to the RFQ process:

- Follow-up documents, i.e. energy audit contract and the actual performance contract, should be on the table at this time. One very large western school district that we assisted, albeit late in the game, went through a process that included the generation of three different contracts. Because the negotiation of the final contract was left until late in the game, there was a fundamental mismatch between what was proposed by all the subcontractors to the ESCo and what was ultimately incorporated into the final performance contract. This caused in a major disagreement between the parties, ultimately resulting in the lawyers on both sides having to get involved.
- Parties to a performance contract (on either side of the table, owner or ESCo) should not sign a contract with anyone whom they don't firmly believe can do the job (on both sides of the table, owner and ESCo)—or whom they don't trust. This is because performance contracting is so intricate and devilishly tricky that the terms of any contract are really just too hard to enforce!

Performance contracting is a design-build process. It can only be negotiated. It cannot be bid.

WHAT TO LOOK FOR IN AN ESCO

Building owners considering performance contracting would be well advised to look for the following in an ESCo:

- Motivation to make the owner's project a success. This is perhaps the most important quality to look for. Owners should examine the ESCo's stake in the success of the project. ESCo's who have an obvious long-term commitment to a particular marketplace will likely have a greater stake in the success of a given project than ESCo's who are operating from the other side of the country using "fly in" staff to sell and run a project. We call this "hiring the local

boys,” whether they are part of a Fortune 500 company or part of a small, local, turnkey performance contracting operation.

- Engineering resources. The ESCo must be able to put into the field an appropriate quality and quantity of both investigative and final design resources. Assisting one community college district, we interviewed firms, and when asking a very large national firm about their engineering resources they responded by naming five local consulting engineering firms in a single breath. This told the owner two things. First, since the range of reputation and expertise of the firms covered the entire spectrum from almost completely unqualified to the best in the business, it indicated to the owner that the ESCo considered engineering simply a commodity and that the ESCo was unable to discern different levels of expertise and quality amongst the engineering firms with whom they had contact. Second, it became clear to the owner that the ESCo did not have an ongoing, committed relationship with any of the engineering firms that were mentioned. Again, it was obvious that the ESCo considered the engineering resource simply a commodity to be purchased by the “truckload” as needed for a given project.
- Installation capability. Few ESCo's will have 100% capability to do piping, ductwork, structural work, and building automation. However, any ESCo worthy of consideration will have significant in-house capability and/or well-established relationships with quality installation contractors. Just as in the case of engineering, this resource should also not be considered a commodity. Quality makes a difference in performance contracting. Frequently, the ability to produce persistent savings in an energy retrofit project is a result of:
 - the quality of the thinking (i.e., engineering) that has gone into investigating the building and identifying opportunities, conceiving the approach to and the details of effecting the retrofit work, and,
 - putting that retrofit in place (i.e., construction) so that it is complete and comprised of components, pieces and parts that will stand the test of time.
- Monitoring and maintenance capability. In the case of the same community college district mentioned above, the ultimately suc-

cessful ESCo was able to demonstrate in their local offices their ability to dial up, talk to, monitor, and influence the operation of a building automation system installed on the other side of the country. They demonstrated this capability live, in front of the client, and they did it with an ease and familiarity that convinced the college district of the ESCo's ability to perform this part of the overall project.

- Sensible and down-to-earth approaches. In our vernacular, we typically say, "myth-spinners need not apply." The foundation of every energy retrofit project is solid, reasonable approaches to changing the fundamental nature and operation of the various building infrastructure systems in practical and efficacious ways. This is not rocket science, nor need it be.
- Track record. Finally, the track record in the local marketplace is probably indispensable. The only exception to this would be when the owner's organization has a wide geographic scope, and a geographically similar ESCo has already proven the ability to perform in the owner's other facilities.

INTERVIEWS

We have a few very proven-effective suggestions for conducting ESCo interviews, as follows:

- Keep the field small. We have seen owners who have lined up 8 or 10 or 12 ESCo's for interviews. This is a mistake. As a matter of policy, the owner's organization should probably limit face-to-face interviews to with no more than 3 performance contractors. If it is not possible for the owner's organization to narrow the field to a number this small, it probably means that the owner's organization hasn't asked for the right information, or needs help (from someone experienced in the field) in order to sort the wheat from the chaff.
- Meet in the ESCo's office. We have unfortunately discovered over the past two decades that some ESCo's will open a local office on the other side of the country from where they are headquartered

and that the local office will consist of a desk and an answering machine. There is no easier way to find out the answer to this question than to meet in the ESCo's local office. This point is really amplified in the following suggestions.

- Look for concrete examples and answers. While generic answers might seem appropriate, it is much more powerful and meaningful if the performance contractor can describe and discuss projects done for other clients which present problems similar to those of the interviewing owner. The more concrete and specific the answers, the better.
- Look for work in progress. One of the advantages of meeting in the ESCo's office is that the ESCo can provide a tour of projects currently in design or currently being monitored. It is also possible that the ESCo may be able to provide a tour of a project that is currently under construction, or recently completed.
- Look for structure and organization. This also includes warm bodies. Another advantage of conducting the interview at the ESCo's local office is the opportunity to see how well organized they are to do business, and how substantial (or insubstantial) their local staff is.

A SURVEY OF THE VENDORS

Those readers that are reasonably familiar with the energy services industry and who have read the history of the performance contracting industry in Chapter 1 (or the World Bank paper mentioned in the references) will understand that the names and locations of the players in this industry are changing rather rapidly.

Rather than attempting to provide a current list of performance contractors, we present a brief list of web sites where lists of firms in the business may be found. Some of the material on these sites is interesting as much for its historical value as anything. We believe that the business of improving and sustaining facility infrastructure systems is one that requires a sustained presence in the industry and that the continued presence of firms found in some of these referenced sites has something

to say about their ability to provide persistent results and service to building owners seeking a long-term performance contract.

- California Energy Commission—*www.energy.ca.gov/efficiency/escotable.html*
- Department of Energy—*www.eren.doe.gov/femp/financing/espc/pdfs/1022qual.pdf*
- Energy Services Coalition—*www.escperform.org/*
- National Association of Energy Service Companies—*www.naesco.org/cgi-bin/finding.cgi*
- NYSERDA—*www.nyserda.org/695escolisting.html*
- Oregon Office of Energy—*www.energy.state.or.us/school/Vendors.htm*

TWO FINAL NOTES

First, the Internet continues to grow in its ability to assist parties seeking information and contacts in a particular field. Those seeking an up-to-date list of performance contractors are well advised, at any time, to perform an Internet search.

Second, put little faith in “pre-approved” lists of firms. From working for government agencies that assemble these lists, we have learned that they are, for a number of reasons, almost universally powerless to discriminate (Oh, you’re not surprised?) and as a result, virtually all that apply are put on the “approved” list.

Chapter 4

Guarantees, Are They Needed, And What Are They Worth?

THE ORIGIN OF PERFORMANCE GUARANTEES

One of the dominant features of performance contracting since its inception has been the inclusion of a performance guarantee. In fact, part of the reason that the business of energy services has gained a new name is the fact that a performance guarantee has generally been an integral part of an energy services or performance contract. What we discovered nearly two decades ago when putting a Fortune 500 temperature control company into the performance contracting business (we created their performance contracting business unit from scratch over a three-year period), was that the most effective sales-related aspect of a performance guarantee was to neutralize potential technical vetoes.

Facilities engineering departments, including all of us who are engaged in the business of facilities engineering, face a significant image hurdle. Unfortunately, facilities engineering folks of all types are not infrequently viewed as “janitors with screwdrivers” in the eyes of upper management. As a result, facilities departments and salespeople trying to get management to consider investing in their infrastructure, are very often met with a management mindset of disbelief, and even disdain. That mindset manifests itself in doubts about the technical and (especially) the financial feasibility of performing an energy retrofit. As a result, facilities engineering groups frequently find themselves at the end of the line at the capital funding “smorgasbord.”

In response to this situation, two sales strategies were developed in the early years of the development of the energy services industry. One of these was to add financing, since disbelieving managers would often say that they could not fund a project, however worthy it might be—their way, often, of having a convenient excuse to say “no” and/or

dodge a real decision about the proposed project. An offer of financing basically called the “bluff” of the decision-making manager and forced that manager into making a real decision on the merits of the project, not on whether or not it could be funded. The second strategy that was developed was to offer a performance guarantee. This performance guarantee not only neutralized the potential veto of a disbelieving engineering and maintenance staff, but it also had the effect of neutralizing the veto of the decision-making manager by providing a foundation beneath the financial success of the project.

So, building owners should realize that the purpose of the performance guarantee is to neutralize a potential veto from the decision-making manager. Furthermore, building owners should recognize that guarantees cost money, due to the added risk being undertaken by the performance contractor, as well as the added administrative burden of monitoring and reporting project results. Interestingly, even a guarantee which is not forthright will still carry this added cost burden.

SOME PROBLEMS WITH MEASUREMENT & VERIFICATION (M&V)

Counting the beans (measurement and verification) is usually the process by which the performance of the project is demonstrated to have (or not) satisfied the guarantee. Similar to many aspects of performance contracting, this is a strongly compelling part of the business proposition of performance contracting. However, just as the entire performance contracting process is often problematic because it is a different process than what most public agencies, and many private agencies, are accustomed to, but there are some fundamental problems associated measurement and verification which introduce their own tricky problems.

First of all, savings cannot be measured! This is not a statement of opinion, but rather one of fact—hard fact. In attempting to measure savings, you are actually trying to measure something that is no longer there. Savings are literally the stream or flow of energy which is no longer flowing. While you can put a clamp-on air ammeter around a wire that's carrying current and measure the current (and the power flow), putting a clamp-on meter around a wire that has no current flowing allows you to measure nothing. Therefore, it is in fact impossible to measure something which no longer exists, which is what savings are.

Further, as explained by Dr. Kelly Kissock of the University of Dayton at the Department of Energy's Cool \$ense forum in September of 1997 at the Presidio in San Francisco, the statistical methods used in measurement and verification are frequently invalid, or at least questionable in their validity. The underlying problem here, as explained by Dr. Kissock, who is an expert on statistical methods, is that virtually all statistical methods are based on the assumption that the subject of the statistics represents a random population. While this might be true about people or plants or animals, buildings, their methods of construction, their occupancy and use, and even the lighting fixtures in a single given building are hardly random at all. In fact, they are each unique. Therefore, statistical methods used for measurement and verification rest on a weak, if not invalid foundation.

Finally, there are the interfering factors. These are manifest, and include, among others, the following:

- bad baseline information (such as a small complex of buildings served by single electric meter, one of which is outlying, and the owner forgets to mention it to his performance contractor)
- failures of new and/or existing equipment resulting in a change in building operations which increases energy use and which the performance contractor (or the owner) may or may not be aware of (say an absorption chiller that dies, and an electric-driven machine is placed in operation in its stead, causing a huge increase in electric demand and cost)
- changes in use and/or occupancy and the documentation thereof (such as the county sheriff's department on one project who had their own federally funded budget to build a fingerprint archival/retrieval computer system in the basement of the county admin building, which the facilities management department for the county was not informed of, coordinated with, or in charge of, since it wasn't their budget; or a two-shift-per-day tenant that moves into a commercial office building and the performance contractor is not informed thereof)
- additions to or demolitions of occupied space (such as one famous national park facility which doubled its occupied square footage)

with a building addition after the energy retrofit project was complete, yet the facility manager expected the utility bill to go down regardless)

- sabotage (such as the assistant chief engineer in one county building who didn't get his promotion to chief and periodically snipped a few wires in the building automation and digital control system, causing the building's HVAC to run continuously instead of on an appropriate time schedule)

And the list goes and on, and on, and on... as long as your imagination can conjure up possibilities.

All of the above, then should convince the reader that the process of measurement and verification is really a lot like counting the horses in a corral—after all the horse have left and a thunderstorm has already blown through the area. It is much less of a science than an art.

MOTIVATIONS AND/OR PLANNING

While measurement and verification is frequently thought of as the last thing which is done on a performance contract, in fact, the planning for and implementation of measurement and verification steps must begin at the very beginning of a project.

The person frequently assigned to accomplish the measurement and verification task is all too often a *low-ranking* "techie" who may not have been there for the planning and implementation of the project and has so little authority in the organization that he/she has no ability to react to or correct problems that may be discovered in the performance of the project. This person may also feel that their job is on the line should negative results be discovered. (See the next paragraph.)

No one (the ESCO and the owner included) really wants to hear that a project is not performing. Imagine yourself as the director of general services for a large county having to turn to the county administrator or the board of supervisors and explain that your multi-million-dollar project was ill-conceived and/or mismanaged and it is now a big black hole sucking funds out of the county's general fund. This is especially so when you're the one who actually went in front of the board of supervisors and convinced them that this innovative financing and project

implementation technology was the “greatest thing since sliced bread.” We also refer to this frequently as the “Jurassic Park Syndrome.” This is very much like the scene in the movie *Jurassic Park* where Jeff Goldblum, who is playing the role of a chaos theorist, asks the computer wizard how they keep track of the animals they’ve released. The computer wizard demonstrates by bringing up a screen of the park with the locations of all the animals indicated by brightly colored “Xs” of a very specific number. Jeff Goldblum goes on to ask, “Well, how do you know how many animals there are?” to which the computer wizard explains that only females have been released and that they know exactly how many animals have been released. At this point in the scene, just for fun, Jeff Goldblum asks the computer wizard to request the computer to locate some 300 animals instead of the 200 believed to be in the park, and indeed, the computer finds the new, much larger number of animals as requested. The explanation of course is that (like certain species of frogs) some of the dinosaurs have transmuted their gender from female to male in order to continue the species. Unfortunately, performance contracting can be much like the computer system looking for animals in *Jurassic Park*, in that frequently *only the correct answer is sought* and all other answers are ignored, dismissed or incapable of being observed by the methods being used.

The final little problem in this neighborhood is the fact that organizations that are most likely to do a bad project (i.e. an unscrupulous and/or inexperienced performance contractor) are simultaneously the least likely to engage in remediation should problems with a project performance be discovered. In its own way this is sort of a self-fulfilling prophecy that has been chronicled by the numerous utility company subsidiaries that have come in to and gone out of business in the last decade, in some cases multiple times for a single utility company.

GUARANTEES... THE BOTTOM LINE

A guarantee is only as good as the willingness of the guarantor to let it be exercised. A problem that we have encountered in this regard is, (for example) a national company with branch offices where the local branch manager and/or performance contracting manager is unwilling to reveal a non-performing project to upper management. This is particularly true if the upper levels of management have viewed performance

guarantees as simply a marketing ploy and have not created financial reserves to pay off on non-performing projects. In one case, we watched the project manager, the service manager and the branch manager from one branch all lose their jobs over a non-performing project. This was, indeed, very discouraging to us.

Another potential problem area in this regard would be a broker who sees his role primarily as placing funds and who intends to stand back and let their subcontractors take the heat should a project fail to perform. Indeed, in the early going in the energy services business, we worked with one national organization that fully expected that the consulting engineer's errors and omissions (E&O) insurance would be sufficient and appropriate to cover any performance guarantee claims that they might encounter. The national organization did not realize that such risks were not insurable as part of a consulting engineer's E&O liability policy. Recalling from Chapter 2 that the performance contractor frequently has in their possession most of the information about the project, an owner "wrestling" with a performance contractor over a savings guarantee may need to bring on board a number of "energy police" just to defend themselves.

In our humble, but well-considered opinion, we believe that unquestionably the best "guarantee" that a building owner (or an ESCo) can establish for a performance contract is proper execution of the entire process (from energy audit to M&V), and simply doing energy efficiency work that makes sense and works correctly. "Minding the store" is, indeed, a very large part of the business of performance contracting.

Chapter 5

Doing the Homework— Investment Grade Audits

INTRODUCTION

Depending upon who you talk to in the performance contracting industry the concept of the “investment grade audit” is either waived aside as a foolishly expensive techno-babble academic exercise—or a critical element in developing a successful project. While it can in fact be either one (mostly depending upon who’s doing the audit), what you will read in this chapter is a rather strong statement of the case in favor of the investment grade audit, in one “flavor” or another. In fact it is not just a statement in favor of investment grade audits, but a statement in favor of doing performance contracting in such a way that the door is opened to investment grade audits and makes them an integral part of the process, rather than an almost “accidental” part of the process. Readers are asked to forgive the author for covering some ground that is covered elsewhere in the book, but it is beneficial to have this chapter stand on its own, even if it does repeat some material.

A PROBLEM EXISTS

One of the problems with the performance contracting industry (or “energy services” as it was known in the early 1980’s when we helped to formulate the industry), is that it has always been sort of a “rogue” business, not falling into any existing category of business, sort of hard to understand, and therefore inclined towards freelancing and not following any particular standards, nor really even having it’s own “standard of care,” as such things are referred to in legal circles. While some have claimed that, as the industry has matured, the “hit-and-run” ESCo’s

are no longer with us, unfortunately nothing could be farther from the truth as new performance contractors emerge daily.

The dichotomy that exists in this industry is that on one hand the business proposition is compellingly simple, but on the other hand the actual implementation is devilishly tricky.

First of all we have to deal with the technical and organizational problems associated with determining actual existing field conditions, figuring out, designing and building a complex retrofit project (like doing a heart transplant on a marathon runner... during a marathon), and then keeping it working when the end users may actually be in resistance to the project (lighting controls, building automation, etc.). After scaling these hurdles, we then have to deal with the fact (as mentioned in the Spring 1998 Energy & Environmental Management [E&EM] article "Measurement & Verification Options") that *savings cannot actually be measured*. That is to say, *cost avoidance* can be accounted for, but the actual stream of savings is a use of energy that no longer exists and it is therefore physically impossible to slap a clamp-on ammeter around it to measure it. Combine this with the owner's greed occasionally getting in the way (*à la Alameda County v. Western Energy Management, et al*) and actually encouraging unethical Energy Service Company (ESCO) behavior, and you have significant potential for calamity—especially when an unwary owner and an unscrupulous ESCO collide, but also when other well-intended parties pursue performance contracting in relative ignorance. Given the rush of Energy Service Providers (ESP's as opposed to ESCO's) to add energy service offerings to their commodity portfolio, such calamities are inevitable (and already occurring).

THE "SALESMAN'S" POINT OF VIEW

I do not present this point of view spuriously. It is real, in many cases fairly held, and it continues to recur as turnover in sales staff takes place every few years. It is, however, largely wrong.

This point of view (perhaps unfairly named) holds that the whole business of performance contracting is simply one of marketing, specifically product packaging and sales. The salesman's point of view is that there is a need in the marketplace and that the smart company (and salesman) simply provides what it is that the customer thinks they need. In this case the project is just a somewhat unique assembly

of widgets (lighting, digital controls, some chillers, perhaps a few rooftop units, etc.), engineering is a commodity at best (in fact it really is only needed to identify the parts needed, not to really do any analysis or design), that energy audits and studies use things like impossible-to-understand-or-prove computer simulations, that it is really the owner's ultimate responsibility to make everything work and that the "guarantee" is only there because the competition offers it as well. Combine this with levels of sales performance bonuses that are generally unprecedented in the HVAC industry, and you have very little motivation for taking the performance contracting process seriously.

And the truth is, given buildings of low complexity, a large inventory of facilities over which to spread risk, a little bias on the salesman's part towards ethical behavior, a company with some actual, practical energy retrofit acumen, and you can actually produce workable projects. But "accidents" don't equal good policy & good procedure—as, for example, a couple of ESCo's learned in the recent past.

The first of these was competing for the large project described in the Summer 1998 E&EM article "What Do Customers Want Besides Lower Energy Costs?" During the interviews at the ESCo's office, one Fortune-500 ESCo responded to an inquiry regarding their engineering resources by rattling off five consulting firms' names in a single breath. What this told us, and the owner, was that this ESCo viewed engineering as a pure commodity (the firms they named ranged in capability from not-good-enough-to-build-a-dog-house to one of the best in the business—frightening indeed!), and that they had so many names meant that they did not have a solid working relationship with any of these firms. This, among other reasons, got them "cut from the squad." Curiously, we later learned that the performance contracting manager (and interview leader) for this ESCo had "learned" the business working for a competitor best known for their marketing rather than execution skills.

The second of these is another Fortune-500 that had signed an audit agreement with a medium sized school district (21 sites, 900,000+ square feet). This one page agreement provided for the ESCo to prepare a "detailed energy audit" (yes, those three words were the entire specification for the audit) for a fee of \$75,000. Upon completion of their work, they presented the owner with a 36 page audit report. This was very disconcerting to the owner, who requested that more detailed information be provided. After a few more submissions by the ESCo (a

total of four, one original and three supplements), we were finally brought in to assist the owner. Amazingly, after four submissions, there was still not a single energy savings calculation in the audit report(s)! When questioned on this later, the ESCo replied, "Well, we don't give our customers detailed information, because they trust us." Based upon our recommendations, the owner insisted that the ESCo fill in the details (in spite of the fact that they trusted their ESCo) and eventually closed the deal on a \$3,000,000 performance contract. The ESCo in this case has still not figured out the folly of their strategy or that it cost them almost a year's delay in the project. This lack of "corporate memory" is one of the bad side effects of rapid turnover in this relatively volatile industry. Indeed, nearly the entire performance contracting team at this branch office had moved on within a year.

A BETTER POINT OF VIEW

A truly better point of view is one which serves the (long-term) best interests of all the parties involved. As developed over nearly two decades of experience in the field, presented in our nationwide seminar on performance contracting and as embodied in the performance contracting program we developed for the State of California (and for our clients like the San Francisco Unified School District) is an open-book, process-oriented, qualification-based, pay-as-you-go approach to performance contracting. This approach is as follows, and due to its very nature opens the door for the use of investment grade audits:

- The owner prepares a preliminary assessment of conservation potential to gauge the opportunity and likelihood of success of a performance contract.
- ESCo's are considered and selected on the basis of their qualifications, in return for which they agree to an open book process and pre-agreed margins and definitions of project costs.
- The ESCo is paid for doing the investment grade audit and must meet a fairly stringent criteria for the audit, including full disclosure of all the audit information, including cost estimates and sub/vendor quotes, and making a commitment to a reasonable

minimum level of savings, or else they do not get paid (see further comment on this below).

- The Owner participates in developing the audit and selecting the final package of retrofit measures to be implemented under the program.
- The parties enter into an Energy Services Agreement (ESA) which is a third-party document that both parties examine at the very beginning of the process, and is finalized following completion of the audit.
- The project is designed, documented, installed and commissioned according to fairly stringent criteria in the ESA.
- Ongoing measurement and verification is conducted for only a fairly short “guarantee demonstration period” (nominally 14 months) following completion of the installation so as to keep M&V costs to a minimum and to focus the concentration of both parties on making sure everything works—rather than waiting for a year or more to even check the results, which is very often the case.

This approach solves virtually all the ills in Performance Contracting which we have discovered in the process of creating a Fortune-500 performance contracting business unit and doing a lot of expert testimony and remediation in this field. Moreover, it solves the major problem of the investment grade audit—that it all too often isn't done.

WHY INVESTMENT GRADE AUDITS ARE IMPORTANT

The foundation of every performance contract or energy services project is a set of technical problems in a facility which cause it to perform poorly and waste energy. It is the act of identifying the problems, or opportunities, developing technically and organizationally workable fixes, and putting those fixes in place that makes the whole process work. Treating the audit like a commodity, then, is like getting your quadruple bypass diagnosis from your physician's receptionist. No

matter how good he is, the receptionist's opinion is of little value. When considering major surgery, nothing short of a Mayo Clinic physical is what most of us would insist upon. Then why do anything less for your building when considering major surgery for it?

Besides laying the foundation for the entire project, the investment grade audit does some other good things for the project as well. These benefits, by the way, BENEFIT THE ESCo as well as the building owner, and include:

- It dramatically increases the retrofit team's familiarity and knowledge of the facility, which will help the savings analysis, cost estimating, design and installation.
- It increases the documentation shared by the parties, which will help to resolve change orders and other potential disputes later in the process.
- It puts the numbers "on the table" so that the owner sees exactly what the costs are and serves to co-opt the owner into the process, which helps to avoid buyer's remorse down the road, but also prevents the unscrupulous ESCo from employing "value pricing" (i.e., exorbitant mark-ups, good for all you "straight-up" ESCo's!!)
- It provides a set of construction documents that allows the more effective management of subcontractors, construction coordination, commissioning, etc.
- It provides a solid base of data for establishing the baseline which will be used during measurement & verification.

In our experience, we have never found a single ethical ESCo who wouldn't "kill" for the chance to open his books in return for being part of a qualifications-based-selection and negotiated contract process. Only those who have admitted to us (no kidding) that their policy is "rape, pillage and burn" have found this approach unworkable. But hey, too bad for them.

THE INVESTMENT GRADE AUDIT DEFINED

So what is this thing we're referring to as an "investment grade audit"? Well, it's a lot of things, but mostly it is a process of investigation and creation and documentation. Our criteria runs quite a few pages in the contract documents we prepare for our clients, but basically it includes the following:

- Energy Accounting. Before anyone even steps into the buildings, the very first step should be the gathering of all the energy data for the facilities and analyzing it to develop energy use and cost indices. This data can be used to triage multiple facilities (such as school districts) into three groups of facilities (big/bad energy "hogs," big-and-moderately bad, small-but-seriously bad, and the "don't waste your time") so that effort on the audit and on the retrofit program can be directed accordingly. We saw one Fortune-500 some years ago spend as much money on 40,000 Btu/sf/yr elementary schools as they did on 100,000 Btu/sf/yr schools for lack of understanding this step (the entire project team all got to find new jobs later, by the way).
- Field surveys. We identify two basic types. The first of these is the "observation" survey during which the auditors look at what is going on in the building—and why. This survey is intended to identify problems (but not yet quantify them). The second type is the "data gathering" survey, in which name plate data, instantaneous measurement or time-series data is gathered for quantification of the energy used and the potential for savings. Following the field survey, the ESCo is required to issue a preliminary report and make a go/no-go recommendation. If the ESCo's commitment to a minimum level of savings that can be financed in a self-funded project cannot be met, this is the time for them to pull out and cut their losses, a far superior choice than having a bunch of ESCo's doing B.S. audits on speculation and "ginning up" savings figures out of the "ether" during a request-for-proposal process.
- Energy balance/computer modeling. As we have explored in numerous papers (and in our Fairmont Press book out in 2000), computerized simulation does not have to be costly, especially if

modest approaches (such as spreadsheet models) are used. While some avoid building simulation due to their perception of its cost, whether it is used or not, at some point an accounting of all the sources and use of energy (sound familiar to you MBAs out there?) must be done. The purpose of the energy balance is to prevent double counting of savings and to keep all the estimates of savings bounded by the energy attributed to the end use process being retrofitted. Don't laugh, one Fortune-500 we know of guaranteed \$150,000 per year in gas savings on a building that only used \$50,000 worth of gas to begin with!

- Energy Conservation Measure (ECM) development. Each ECM under consideration should have developed for it an outline scope of work, preliminary sizing calculations, preliminary equipment selection, sketches (for complicated ECM's), detailed cost estimates, and both a statement of the principles of how the ECM will save energy and how that energy savings will be estimated (e.g., "air handlers run at night when it is cool and the space served needs cooling—we will add outside air economizers for "free" cooling and simulate on DOE-2 by adding economizers to the retrofitted air handling systems").
- Detailed savings calculations. Someone at some point has to sit down and say what they think the savings from a given retrofit is going to be. This needs to be documented, by type of energy saved, by piece of equipment being modified, as a percent of the equipment/end use being modified (numbers greater than 100 not allowed) and the M&V approach planned for the retrofit (yes, M&V starts at the beginning, not the end of the project).
- Audit report. All the data gathered above and all of the analysis needs to be bundled up in the final report. This report should be presented to the owner in draft form, the ECM "package" discussed and negotiated, and the report finalized.

Our standards for doing this work (see Appendix) also include criteria for the engineer performing the audit as well. Generally we are looking for engineers other than traditional consultants who do new construction primarily, as it is rare that they have retrofit expertise.

Similarly, we avoid what we call the “study kings,” i.e., those firms that have traditionally specialized in audit work for “low buck” government agencies and have little expertise in designing and commissioning actual projects. We generally look for design-build experience, control system experience and building simulation experience in selecting consultants for our clients. Building owners are cautioned here as many of the folks out there in the performance contracting business are unable to discriminate between competent energy engineers and the rest, which unfortunately reinforces the “salesman’s” point of view discussed above.

Now, the above describes a pretty rigorous process, and if you’re doing a 1,000,000-square-foot high-rise in the center of town, this is definitely the way to go. However, as we have alluded to, if you’re working with an elementary school district (for example), a much “lighter” approach would make sense. We would still call this an investment grade audit, though the level of site investigation and the rigor of the energy balance/building simulation would be significantly relaxed. The documentation would be commensurately lighter as well, though we would still expect it to be fully comprehensive in nature.

As a rule of thumb, we expect to spend 10¢ to 30¢ per square foot, or 5% to 10% of the annual energy bill in doing investment grade audits. Generally this represents a value in a range of 5% to 10% of the overall value of the project. This is another area where intimate involvement between the owner’s and the ESCo’s organization is important, because the allocation of the engineering resources to the various facilities should really be a collaborative endeavor.

FINAL WORDS

To some, this rigorous form of energy audit is new. Well, some energy engineers, your author included, have been doing instrumented surveys and investment grade audits since the late 1970’s. At that time we could not imagine asking our employers to “roll the dice” on anything but a rigorously performed audit. In fact we found it both curious and frustrating that only government agencies and other institutions felt that “ordinary” audits lacking in rigor, were acceptable. We could only conclude that accountability apparently had a lot to do with the judgment of what was acceptable. Perhaps this also explains

why the vernacular 20 years ago used by real energy engineers when referring to rigorous audits was “engineering feasibility studies,” in order to avoid the stigma of the term “audit.” To close, we believe that it is important to observe that not a single project that has followed our process has ever come to naught. While some have bemoaned the “high cost” of investment grade audits, we can think of no better (or cheaper) “insurance” for success than doing the homework, and doing it right.

Chapter 6

Building Simulation And Performance Contracting

THE LITTLE-KNOWN “DARK SIDE” OF PERFORMANCE CONTRACTING

While it has carried many names over the past few decades, such as “energy services,” “demand side management,” and “performance contracting,” the process of implementing energy conservation and energy cost management programs on a turnkey basis, generally including financing and a guarantee, is what we today call Performance Contracting. And, as of the writing of this book, it has gained great popularity and seems to be particularly bolstered by the wave of electric utility deregulation which is in the process of sweeping the country. When done properly, as explained in our Association of Energy Engineers seminar entitled *“Management, Measurement, and Verification of Performance Contracts”* and in Chapter 2, performance contracting has the ability to integrate financial, engineering, construction, operations, and maintenance services in a way that often produces spectacular results which could not be achieved by any other means.

Performance contracting, however, does have its dark side. Because the business proposition is so attractive and compelling, it is frequently viewed literally as a “guaranteed free lunch” by numerous building owners. However, in spite of the essential simplicity of the business proposition, the implementation is anything but simple. The soft underbelly of performance contracting, is the unfortunate and unavoidable fact that *savings cannot be measured*.

Now this would seem to fly in the face of the measurement and verification contingent, but the truth is, savings themselves cannot in fact be directly measured. You see, energy savings are the units of energy that are no longer being used. That is, they are things that are no longer

there—and you can't measure that which doesn't exist—you can only estimate the space they would have occupied had they existed. It is possible to measure the energy that was being consumed prior to performing the energy retrofit, and it is possible to measure the energy being used after the retrofit is implemented. One can conclude, then, that the difference between the two measurements is, of course, the "savings." However, and this is a big however, the pre-retrofit state of the building (the "baseline") no longer exists once the building is retrofitted, and what that "baseline" would have become in the future can never be absolutely known. This is because the number of factors that can affect building energy use is great and includes changes in the size of the building, changes in the building's occupancy and use, failures of existing equipment and control systems, changes in building operations (such as caused by a new operating engineer), etc., etc., etc.

It *is* possible to do an accounting of the cost avoidance produced by an energy retrofit project, but this accounting is the product of a lot of measurements and a whole lot more assumptions and calculations. Because this demonstration of performance contract results (the counting of the invisible "beans" if you would have it) is very nebulous at times, minor disasters occur when the unwitting or unwary building owner collides with an unscrupulous ESCO. Those not so sure of the problems in this regard should read two documents mentioned in the bibliography; the Energy & Environmental Management article "How to Marry an ESCO," and the State of Arizona Auditor General's report entitled "Energy-Saving Devices and Services Budgeted for by School Districts."

Because "God (and the devil) is in the details" when it comes to performance contracting, we unalterably recommend to our clients that the entire process of performance contracting be well-managed, from the beginning to the very end. This is in contrast to what we believe is the biggest and most serious mistake being made in performance contracting at this time, which is to place too much reliance on measurement and verification, treating it as the first line of defense, and the only portion of the project requiring attentive management. This approach is simply the road to ruin.

Furthermore, since the foundation from which a performance contract springs is the technical inefficiency inherent in the existing building's design, construction and operation, we also suggest with great strength that the investment grade energy audit, or detailed engineering feasibility study, be given primary emphasis, care, and attention. This

engineering endeavor is much like a Mayo Clinic physical that determines whether the patient's heart will be removed and replaced or whether the patient will be placed on a new diet and exercise regimen. Because it creates the entire foundation for a performance contract, the investment grade audit is the last place in the entire performance contracting process where shortcuts should be taken or costs cut. Once the importance of the detailed feasibility study is grasped, then the importance of building simulation can likewise be grasped, because it should be the key tool of choice for performing the detailed feasibility study.

Computerized building simulation is the key tool for performing detailed feasibility studies for a great number of reasons, including:

- It confirms the auditor's knowledge of the building.
- It provides an energy balance
- It identifies energy conservation opportunities
- It documents the baseline conditions
- It provides a foundation for future adjustments to the contract baseline
- It builds confidence and teamwork, helping the project (and the ESCo's sale) to proceed

BENEFITS FROM BUILDING SIMULATION

Assuming that the computerized building model is constructed along the lines described in *Computerized Building Energy Simulation*, published by The Fairmont Press, a considerable number of benefits accrue from the use of building simulation in performance contracting, as follows below.

Confirming the Auditor's Knowledge of the Building

The process of building and calibrating the model causes an interesting thing to take place in the mind of the energy engineer performing the audit. As a byproduct of the process, the auditor ultimately winds up confirming their knowledge of the building, i.e., that they know most every energy-using system and/or equipment that exists in the building and that they know pretty much what happens in the building with those systems and equipment. The upshot of this is that the auditor may now proceed with developing his project in near-complete possession of

the truth and may perform his work without having to guess or speculate, at least not very much at all.

Creating an Energy Balance of the Building

The foundations of the project are the technical ways of improving the operation of the building and thereby reducing the use and cost of energy, producing the cash flow stream which ultimately pays for everything. Now, if the auditor's estimates of potential energy savings are flawed, then the entire project is flawed. This means that the energy engineer's estimates of savings must be accurate. For example, if there is a lot more desktop equipment in a building than what the auditor thinks, and he is too lazy to measure the actual connected power draw of the HVAC fans, he might incorrectly allocate this "plug" load to the fans. Well, if a variable volume retrofit of the HVAC system is planned, then the estimate of savings generated by the computer simulation model will be much greater than the actual savings produced by this retrofit—unless the auditor makes a convenient (and completely accidental) counterbalancing error in his simulation of the variable volume retrofit. Unfortunately many, perhaps especially those enamored of measurement & verification, eschew the preparation of an energy balance, saying that they only measure the equipment they intend to retrofit and will perform M&V on that same equipment afterwards. The problem here is that a short term measurement won't capture a major change in building occupancy or operation that occurred just prior to the audit (e.g. the HVAC timeclock suddenly dying), and that perhaps the building owner isn't even aware of! So the auditor monitors 24-hour a day operation of the HVAC, bases his savings on this "baseline" (actually a false baseline) and is then later surprised when the owner objects to the post-retrofit "invoice" for savings. Doing an energy balance will catch such "tunnel vision" errors. By doing an energy balance (in essence, calibrating the simulation model), all the uses of energy are correctly allocated and the savings projections based thereupon are dramatically more likely to be accurate, and will ultimately result in a more successful project.

Identifying Energy Conservation Opportunities

One attendee at our performance contracting seminar observed that frequently the reason that the energy balance cannot be completed and/or the model not calibrated, is because there is an as-yet-undiscovered energy conservation opportunity! That is, something is operating out of

control, unbeknownst to the auditor—say the chillers are being left in operation during cold weather (would you believe a 100 kW chiller load in the middle of the night in the middle of the winter in an Austin Texas college dormitory?). Because the auditor does not know this is happening, his model won't calibrate and sources and uses of energy won't balance. The lazy auditor may just make a "fudge" change to the model and call it a day. However, the earnest auditor will ponder the problem and research the building and the existing documentation to ferret out the reason—and will often be rewarded with a "pot of gold" for his efforts! Yes, it really is this simple (or complex) at times.

Documenting the Baseline Conditions

One of the benefits, particularly for the ESCo, is the fact that a well constructed model, with its supporting documentation, is a detailed statement of the baseline conditions. In one project, we were called back by the ESCo after the project was in operation for a year and the savings guarantee wasn't being met. Among other things, we re-took the electrical readings on the power distribution panels on each floor—at the exact same locations the readings were taken during the audit (each was marked with a sticker with the ESCo's logo and a code name). One thing we discovered was that the desktop equipment load (the "plug" load) had increased some 30% since the audit—amounting to more than 1,000,000 kWh (worth some \$100,000) per year! While this was not the only problem with the project, it did save the ESCo a lot of money, and was a problem against which he would have been defenseless had the original computer model/energy balance not been performed!

Providing the Foundation for Future Adjustments to the Baseline

The example immediately above leads immediately into adjusting the baseline once a change in the baseline conditions has been identified. In the case above, the increased "plug" load was input to the original model and the contract baseline equitably adjusted—without dispute on the part of the owner. This adjustment, incidentally, took into account interactive effects, such as the added air conditioning load imposed by the increase in desktop equipment, as well.

Building Confidence and Teamwork

While it is hard to put a value on this side-effect of building simulation, once the survey team has been in the building observing and

documenting existing conditions, and once this information is converted into a calibrated model of the building, the project team, including the owner, can have a very high level of confidence in the veracity of the audit process. Blind faith is great, but faith based on knowledge is unsatisfiable. In our experience we have seen the ESCo's sale made at the exact moment in time when the building owner realized that the audit and retrofit team, in a very short period of time, had exceeded his own in-house staffs' knowledge of the building, and that the ESCo's team understood perfectly well how to make the building better!

CONCLUSION

What I hope you'll go away with from reading this chapter is that computerized building simulation offers many benefits to the business of performance contracting. To fail to use it, even on smaller, simpler buildings, (perhaps with a simple spreadsheet model) is a mistake not worth making.

Chapter 7

Energy Audit Case Studies

So you might ask, “What is all this survey stuff in Chapters 5 and 6? Why can’t we just use the as-builts, it’s an awful lot easier and it’s just as good, isn’t it?” Hopefully that’s not what you are thinking. However, some people look at the amount of work involved in an investment grade audit, and say, “Can’t we just use the as-builts?” This chapter is intended to share with you some of my personal experience doing energy audits, things that I wouldn’t have discovered if I hadn’t become what I would call an “HVAC Sherlock Holmes.”

C.Z. BUILDING (San Francisco)

This is a building in San Francisco, California, on Market Street, where we did an investment grade audit with a Trace simulation some years ago. It is a very good example. I was cruising around the building late at night and at one point sat monitoring the graphic control panel in the watch engineer’s office. It was an old pneumatic graphic display panel which showed all the temperatures and other parameters of the HVAC systems throughout the building. Well, I was taking notes, looking at the panel, recording temperatures, etc., and as I looked up from my note pad, all of the temperatures started changing and all the dials started moving. It looked like the control panel of a diving submarine, and I half expected a klaxon alarm to sound. It was fascinating, and I realized that while I had my head down writing notes, that the watch engineer had walked through the room. He didn’t even really stop, he just came through the room. So I walked around and found him and I said, “Did you do something when you came through the room?” He replied sheepishly, “Oh, yeah.” So I said, “Well, what did you do?” He said, “Well I put the outside air back on automatic.” I inquired, “Why did you put it back on automatic?” He said, “Well, ‘cause I put it on manual

earlier." "Okay," I said, "Why did you put it on manual?"

To make a long story even longer, it turned out that the supply air for the basement (which is where the engineers' office was), was return air from the lower four stories of the building. Basically, they pumped air that was being thrown away into the parking garage and into the spaces that were occupied down there (I don't believe that the engineers' office even existed in the original design of the building). They turned the chillers off at 6 p.m., but they left the interior terminal reheat system, serving the core of the building, in continuous operation. The engineers' office would get warm because the entire building got warm, what with the lights still on for the janitors. John, the watch engineer, had discovered, ten years or more prior, that if he manually put the outside air economizers on full outside air, that all night long while he was there, the typical 50°-year-round nighttime air in San Francisco was too cold for the reheat coils upstairs to keep up with, and the temperature in the entire building (half a million square feet) would drop three or four degrees, and in turn it kept his office a little cooler! So, by understanding this "daisy-chain" of circumstances, we determined that this was going on every night of the year whenever John wasn't on vacation. As a result, we modeled this building at an average of 70% minimum outside air. The result was that our computer model was within 5% of the actual energy bills—on the first run! We couldn't have done that without knowing that John was messing with the controls. The solution to the problem, by the way, was to put in a small split-system air conditioning unit in the engineers' office, so John wouldn't have to try to heat all the ambient air in San Francisco every night.

That's One.

C. PLAZA BUILDING (San Francisco)

Another building in San Francisco, California (half-million square feet). We're talking to the operating engineer, and he has a "patch panel" in his Chief Engineers' office. The patch panel is almost like a telephone switchboard, where one pulls the cords out and plugs them back in to change the operation of the panel. Their "fancy" energy management system had four or five or six time clocks in the panel, each constituting a "channel" for time control. One could take the cords from any air handling unit, for example, pull them over and plug them in to the time

channel desired for that air handler. For a 1960's design, it was actually a pretty neat idea. The Chief Engineer advised us that they started the building at 7:00 a.m. then turned it off at 6:00 p.m., i.e., that's when all the air handling equipment started and stopped.

As part of our study, we got the demand interval records from the utility company. We checked it out and noticed that something was not right. The demand interval data showed a big load coming on line at 6:00 a.m. and off at 7:00 p.m.! Not at all like the Chief Engineer said. We went back to the building and looked more closely at the "patch" panel. It seems there was one clock that was set for 7:00 a.m. to 6:00 p.m. and right below it was a clock that was set for 6:00 a.m. to 7:00 p.m. Same numbers, they were just in the opposite sequence. Well, it turns out that the Chief had everything plugged into the wrong "channel." He thought that the building was running a certain way—and it wasn't at all. This was the guy that was in charge, and really should have known, but he didn't.

So, he had an extra two hours of operation that he didn't need, (nobody was there at 6 o'clock in the morning). We were able to get that model right because we modeled the operating hours correctly, not as we were told. In addition, we were very confident that our operating-hour savings would net us a certain 15% savings (2 hours/13 hours)!

That's Two.

B.A. BUILDING (Pasadena)

A quarter-million-square-foot office building in Pasadena, California.

Here's another chief engineer situation. I was surveying the building and I talked to the chief and I said, "Do you guys do anything to turn the equipment on and off, that sort of thing." Well, this was a building where they had no wall switches for the lighting (an early 1970's building). All they had was breaker panels and the operating engineers were in charge of going around and turning the lights on and off. The building was made up of 50,000-square-foot floors, each floor being two mirror image 25,000-square-foot pieces. The electrical panels were similar, with matching panels on opposite sides at one end of the floor. All the HVAC ducts, all the power wiring, everything was mirror image. So, as the Chief explained, they had an "energy management program" which was

manually implemented. The operating engineers would were supposed to visit each floor and turn off the lighting at the end of the work week (they worked three shifts a day in this building, but they didn't work weekends).

So, we modeled the building according to what the Chief told us. But when we started comparing the model's energy consumption to the actual energy consumption, we couldn't get them to match. We were missing about a million kilowatt hours per year.

To investigate this discrepancy, we pulled out the 15-minute demand interval data and started looking at it. What we discovered was that on the weekends they weren't turning the lights off. After further interrogation of the Chief Engineer, he reluctantly said, "Well, yeah, we used to do that, but we discovered the 300-ton centrifugal chiller we were running in the middle of the night, to support the 30-ton computer room load, would cycle off if the lights weren't on." The cycling was due to low refrigerant temperature, and the chiller had a 30 minute timer so it wouldn't start back up again. By the time the chiller restarted, they'd lose temperature control in the computer room. The easy solution was just leave the lights on—a quarter-million square feet of lights. It was a nice solution, and it kept that chiller running just smooth as silk. And that's the kind of thing that chief engineers do. He told me, by the way, that he'd asked management for a new low-load chiller for years (all he had was two identical 300-ton machines), but they'd never listened to him. He even showed me a quotation he had gotten for a new small chiller from a vendor (of course the quote didn't include installation, and no one had calculated the savings it could achieve).

So, we revised the lighting schedule and we got the model to come out just right—with only this one change. Of course the retrofit project we sold included a little reciprocating chiller to run at night to take care of that 30-ton computer room load, and a lighting control system so that we could get the lights shut off, along with override buttons in the hallways, so the occupants could override if needed.

That's Three.

A.S. BUILDING (Houston)

Here's a 100,000-square-foot office building in Houston, Texas. Talking to the building manager, we mentioned that we had no-

ticed that his building and the building next door were diagonal to each other, and in the spot between the two buildings, was a parking garage. We asked if it was their parking garage, and they said "Yes and no, we share it with the other building." So I asked who was paying for the lights, and he said, "Well, half the lights are on our circuits and half are on theirs." Of course my "antennae started quivering," realizing that such an arrangement was not one that any respectable electrical engineer would ever allow.

So, we went out in the middle of the night, got the parking garage security guys involved, and shut off the big circuit breaker in the main switchboard of our building—and the whole garage "disappeared." No elevators, no lights, no nothing—one breaker.

We helped that building manager renegotiate a relationship with the neighboring building who was getting to use half of the parking garage at no expense. The problem was that the other building was built after the building with the parking garage and everybody was assuming they were sharing the cost. But they weren't sharing the cost at all.

Needless to say, our model wouldn't have been correct if we had not identified that little problem.

That's Four.

A.S. BUILDING (Houston)

Same building in Houston, Texas.

The building looks like an energy hog based on the utility data. Btu per square foot is high, dollars per square foot per year is high. It looks bad (well, good, actually).

We find out that they have a computer room in the building and that they are submetering the computer room and they are charging that department for the cost of the power (this is an owner-occupied building). They were letting the Management Information Department or whatever they called them, pay for the cost of running the computer room out of their budget. A good idea.

As part of our survey of the building we wanted to perform a quick check on the submeter. So we stuck an instrument on the service going to the computer room and watched it for a day or two and we also got the monthly internal invoices that they were sending off to the Management Information Department. The two didn't seem agree. Well, it turns

out the meter was installed by a local electrical contractor and he forgot to pencil in the meter constant. Depending on what kind of current transformers one installs with the meter, one gets a different constant. The constant can be 1 or 10 or 20 or 30 or 40. They were reading the meter wrong from the day it was installed. The correct meter constant was 20, while they had assumed it was 10. It turned out then that the computer room didn't use 25% of the building's total electrical use, it used 50%! It was a very, very energy intensive computer room. So we changed our electrical loads that we modeled in the computer, and we got the model right.

Unfortunately, however, there was not a project in that building. When one took out that computer room and its air conditioning from the building, the building itself was actually a very energy conservative building. In that case we didn't discover this until we were essentially finished with the detailed study. It was embarrassing, but it was a lesson that if there's any reason to stop a study, one had better stop sooner rather than later, because it's embarrassing to spend a bunch of money doing a detailed investigation, and then publish a report that says, "Sorry, dry hole." Our standard practice is to stop at the end of the field survey and regroup and make a specific, considered decision whether or not to continue the feasibility study.

That's Five.

P.Z. BUILDING (Houston)

Here's another good one. A 1.8-million-square-foot office building in Houston, Texas.

We were looking at the gas bills and 15 minute demand interval data from the utility company and we discovered two things.

First, looking at the demand interval records we observed that there was a huge electrical load in the middle of the night for no apparent reason. We spoke with the operating engineers to find out why. The reason was they had a small data center in the building, but their smallest chiller was 1,500 tons in capacity. In order to keep the chiller on line the operating engineers would run an extra twenty air handling units all night long to keep some load on the chiller.

Second, the natural gas bills over the previous three years were \$50,000, then \$100,000, then \$50,000 again. Upon investigation, we

learned that over the three-year period there were two different chief engineers. One guy went away for years and then came back, and the guy that was there in between didn't know the building all that well, so he let the boilers run way too long. In Houston there is only about a month to two months of weather that really need serious heating. In a lot of the buildings in Houston, the operating engineers only run the boilers a little bit in December, all of January and some of February. The guy who was there in the intermediate year was afraid of having comfort problems, so he ran the boilers for nearly six months, doubling the gas bill.

In response to this information we first had to decide which year we were going to use as our base year. Complicating the situation was the fact that the energy services company we were working for had a very aggressive sales person who didn't want to use our conservative computer simulation results, and guaranteed the customer \$150,000 a year in gas savings. It's really hard to create \$150,000 in savings out of \$50,000 or \$100,000 in costs. The ESCo (a Fortune 500, by the way) ended up in a "world of hurt" on this project. They also ended up asking that sales engineer to leave the company—who had grabbed his commission on the sale and hustled to an office in another state, but was still working for the same company. He discovered, much to his chagrin that, as the saying goes, "You can run, but you cannot hide."

Because of the information we found out, we were able to model the building very accurately (especially with the 6,000 electrical readings we took and the monitoring of overnight chiller loads as well—500 tons in the middle of the night—in the winter). We modeled an average of the three year's gas use as being "characteristic" of the base period and used a three-year average for our baseline condition. There were good retrofits to do, including lighting, better time control on air handling units (they grouped units in groups of 10), and a nighttime chiller of 500-ton capacity for light loads.

However, the sales engineer didn't like our conservative estimates of savings, especially with respect to digital controls (there really wasn't any mixing that digital controls could correct), so he substituted his own calculations for ours and passed off the final report as ours to his management. Unfortunately, given the large bureaucracy that they are, no one at their headquarters happened to call us to discuss "our" report, nor did they happen to notice that the guaranteed gas savings was twice the three-year average total cost. They did start to pay attention after the first

year's saving were far short of the guarantee, and we did get the (slight) satisfaction of getting to do the expert testimony on this project, including a post-retrofit audit of the entire project. It was subsequent to our audit report that the sales engineer in question was asked to leave his employer.

That's Six.

D.M.D. BUILDING (San Mateo)

This building is a very interesting case study regarding temperature controls in an 85,000-square-foot office building in northern California.

(By the way, this building is the subject of a class exercise in our computer simulation seminar and our energy auditing class at Berkeley.)

From observing the building, it was clear that this building was suffering from what we refer to as "zero maintenance syndrome." There was literally no money being spent to maintain the HVAC systems in this building. In addition, the energy use was something like 165,000 Btu per square foot per year—almost as high as an acute care hospital.

In talking with the maintenance man (one really could not in justice call him an operating engineer), it was clear that he was having a lot of trouble maintaining comfort in the building. In particular, he complained that he had to start the building earlier and earlier in order to get the building warmed up for morning occupancy—and still the tenants were not happy. In addition, he said that he could not keep the sunny side of the building cool in the afternoons without freezing the shady side of the building.

Part of the problem, we learned from examining the HVAC system, was that the building was equipped with an odd, single, air handling system which was a combination multi-zone, variable volume, high-pressure-induction system! The main air handling system was a double duct unit with field-fabricated mixing dampers right at the unit (making it a multi-zone unit), with one zone serving the core of the building (which was equipped with Carrier Modu-Line VAV terminals—making that portion variable volume) and three zones serving three exterior zones of the building (which were equipped with under-window high pressure induction terminals—making that portion high pressure induction). Certainly this would not be an easy system to operate under the best of circumstances.

In observing the building operation one afternoon, I noticed that the refrigeration compressor was running and the boiler was cranking along at a good pace as well. Interestingly, the supply temperature to the interior zone was not particularly cold, nor was the supply temperature to the perimeter zones very warm, even though the dampers for each of the zones were in full cooling and heating respectively. I promised the maintenance man that I'd keep his tenants happy the following day.

At 4:30 a.m. the following morning, I found the heating and cooling both going full blast—and only 68 degree air going down the perimeter zones. It's very hard to heat a building to 70 degrees or so with 68 degree air. Adjusting the refrigeration controls, I got the compressors to shut down. Now the heating had a chance to work and we got 100+ degree air down to the perimeter zones. I continued my survey of the building and also discovered that the Modu-Line VAV terminals were filthy dirty and as a result, many of the terminals were stuck about half open, resulting in over-cooling of the spaces being served. In the key complaint areas I worked the terminal controls a bit to free them up and they began to function once again.

As the building warmed up that day, I reset the boiler controls and got the boiler circulating pump to shut down. I also adjusted the refrigeration controls a bit and got the air conditioning compressors back in operation. The building had a partial outside air economizer, but this had been disabled since there were no provisions for relieving air from the building—only for bringing it in.

Even with the compressor running, we still could not get very cold supply air—only about 65 degrees—which was not good enough by midday with a lot of solar load on the south side of the building. Inspecting the zone dampers it became clear that the dampers themselves were incredibly sloppy and leaky, even when fully in one direction. In addition, the damper linkages were so worn as to barely stay together. As a stopgap measure, I jury-rigged the core zone into full cooling mode. However, this still only produced slightly colder air to the zone, yet the cold deck discharge temperature was close to 55 degrees! Curious, I measured the hot deck and found it at 85 degrees—with the boiler circulating pump off! Examining the pump I discovered that it was not equipped with a check valve, and I could feel heat in the piping at the heating coil in the hot deck. Suspicious, I valved off the heating hot water and discovered that the hot deck cooled right off, and the supply air to the core zone dropped as well. It seems the boiler was

thermosyphoning, or circulating naturally due to the different densities in the water at different locations in the system—as is commonly done in solar domestic water heating systems where the tank is mounted above the collector.

A few more tweaks on the core zone dampers to see if we could get 100% cold deck air to the core zone. This was somewhat effective, and we had about 60 degree air going to the VAV terminals throughout the building.

After all this messing around, the maintenance man was astounded that both the sunny and shady sides of the building were comfortable. Too bad I had to return all the equipment to their original settings.

The upshot was that to model this building one had to model unbelievably poor operating conditions. In fact, the utility company representative who reviewed the model used for the rebate calculations was unwilling to believe that a savings percentage as high as we were projecting was possible. His problem was that he didn't realize how horribly inefficient the existing system was. After all, it ran all night long mixing heating and cooling so the building could still be uncomfortable all day long!

That's Seven.

V.F. CENTER (San Jose)

Here's another real good case study, focusing on temperature controls as well.

This building was in San Jose, California. It was a very high energy user. The Btu per square foot per year was really high, something like 150,000, and the cost was really high as well.

The operating engineer was telling us that he couldn't get the building warmed up for morning occupancy. He kept setting the time clock earlier and earlier and earlier. Another interesting case, indeed.

At 2 o'clock in the morning I was standing outside the building at the entrance to the elevator. Now, even though I was outside and it was 42 degrees out, I was "toasty" warm! Very strange. Now, what was interesting about this building was that the elevator lobby was outdoors. What they did when they built the building was to basically cut a hole through the first floor so that one could walk up to the elevators from outside. What this meant as well was that the stucco ceiling above one's

head when waiting for the elevators was really the bottom of the ceiling plenum on the first floor. Feeling all toasty warm, I realized that the warmth I was feeling was coming from over my head—from a grill in the stucco over my head!

Investigating this curious phenomenon, I discovered that the building had been retrofitted with outside air economizers about ten years prior. It was a simple installation with a modulating mixed air controller and a high ambient lockout as well. The installers were smart enough, when they put the economizer in, to put in a return air low temperature lockout as well. When the return air was below 68°, they locked out the economizer. And that probably wouldn't have been too bad except that the economizer either failed or was adjusted so that it went to 100% outside air whenever it was working. So the reason that they couldn't get the building warm was the fact that the building would start to warm up, the return air would reach 68 and the economizer control would go out of lock up, and the air handler would pump 100% of 42° outside air into the building. Next the building would cool back down below 68° return temperature (because the reheat coils in the ducts just weren't powerful enough to fight 42 degree air), and as a result the economizer lockout control would energize again, locking out the economizer and the building would warm up to 68° once again. The building would go through this warm up and cool-down cycle about every 30 to 45 minutes all night long—with the building never getting any warmer than about 68 degrees!

Of course the operating engineer, rather than diagnosing the problem, said if the building is not warm, we must need to start it earlier. He normally would start it about 7 o'clock in the summer so he moved it up to six, moved it up to five, moved it up to four, moved it up to three, moved it up to two, moved it up to one, and finally moved it up to midnight. Basically, he had the building running from midnight on, with the control system that kept the building at 68° for eight hours before occupancy—just grinding away using fan power and boiler energy.

If we hadn't talked to the operating engineer to find out what he was doing, and if we hadn't observed the controls and happened to be standing there beneath this flood of hot air coming out of the building at 2:00 in the morning, we wouldn't have been able to figure all this out—and our computer model would have been junk—no matter how good a modeler we were. This is not the kind of data one can get from the as-built drawings.

COMMENTS ON THE SURVEY CASE STUDIES

A lot of what we found in these case studies are simply by-products of the human infrastructure operating the building. Some might say that the real solution in many cases was to fire the stupid operating engineer who was messing up. We tend to believe, however, that operating engineers exist to operate the machinery we give them, and that they're operating buildings instead of designing them for a reason—and that many design engineers wouldn't be a whole lot better operating them either. So, rather than "shooting" the "guilty" parties, we believe in creating a building system infrastructure that institutionalizes good practices and works with the human infrastructure, rather than against it. After all, a one-ton split system in the engineers' office is a cheap way to get the operating engineers' "buy in" on a million dollar project. We believe that in the long run this strategy will achieve the best and most persistent results.

As a corollary to the comment above, we have found that it is also a good practice not to turn an energy retrofit feasibility study (or "audit," if you would) into a "witch hunt." It is very easy to fall into the (egotistical) trap of using the audit to show how "smart" the auditor is and how "dumb" the operating engineers (or building designers) are. A lot of operating engineers suspect that this is exactly what an energy audit is likely to be, and "clam up" as a result. As mentioned above, the operating engineers may not always have the right information, but they do know the "facts" about problems and idiosyncrasies of their building, and they most always lead the way towards insight into the potentially enigmatic aspects of the building. Besides, the job of the operating engineers is to operate the building, not re-design it—and it's a minor miracle they can keep some of these buildings running at all! We have found that a successful strategy is to ask the operating engineers for their "wish list," with the promise to see what we can do to find the funds to implement their good ideas, ideas that management has likely been ignoring for some years (after all, who's going to listen to a "janitor with a screwdriver?"). Indeed, this strategy has paid dividends more than a few times—and won us a lot of allies in the process.

As a final comment on site surveys, it is our policy is to do a survey of the building only if we get a set, usually two sets, of master keys. And we don't mind if we have to leave them at the building, and sign them in and out at a security desk. Almost without exception, we will not

allow the building owner to require that we have an operating engineer accompany us on our survey, because we don't get anything done in that case. The one time we allowed the building owner to require that the operating engineers accompany us, it was because the owner didn't want to sign out keys. When we had to wait on the operating engineer, we were stuck, because he was on call and frequently left us with the comment, "I'll be right back." So 45 minutes later, when we were done in five minutes, he finally showed up again. What building owners also don't realize is that in a good survey one may go back and forth numerous times to the same locations to re-check information or observe the current status of a piece of equipment. In 20 years we've only failed twice to get master keys. On one occasion we even refused to do the project without the keys. So we get in everywhere—with a few exceptions. If there's a vault or some other area that is highly secure, we're not going in there because we really don't want to, and probably because there's not much to see anyway. Computer rooms usually have some kind of a key code or require a badge. We're always getting people to give us badges in the buildings, and we try to make friends with the people. Usually, if they have seen us around there for a couple of days, they know we haven't stolen anything yet, they can see that we are doing our job, and they start to relax a little bit. Locked doors can be a problem and they can prevent you from getting your job done during a survey, so it's important to have as much access as possible.

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Chapter 8

Design, Construction and Commissioning

As we have said previously in this book, the essence of performance contracting is that it is a design-build process. Unfortunately, a considerable number of building owners do not have experience with the design-build process because they have always employed the design-bid process in the past. Therefore, the building owner sometimes forgets that he needs to be concerned about the design phase of the project even though it is no longer in his hands.

With rare exceptions, the installation and construction work on a performance contract always needs to be designed in a somewhat formal process. An example of such an exception might be the installation of motion detection controls. The use of such devices is at times very occupant-sensitive, and it may therefore make sense to make decisions about where to install such devices on a room-by-room, case-by-case basis, with the operations and maintenance staff intimately involved in this process. Of course, once the devices are installed, some documentation of their as-built location should be provided for the record.

Formal design documentation serves a number of functions including the following:

- It provides a communications and approval device between the ESCo and the owner, showing the scope and nature of the work to be done in advance of the actual work being performed.
- It assists the trades in installing the work, providing both an overall road map and details, where needed.
- It provides a permanent record for future maintenance work and troubleshooting assistance, by the performance contractor, and by

the owner once they take complete responsibility for operations and maintenance of the retrofit work.

Because of the importance of formal design documentation, no construction or installation work should start on a retrofit project until the design documentation is approved by the owner.

DESIGN DOCUMENTATION

The plus side of the documentation generated as part of a design-build project is that it can be significantly streamlined compared to design-bid documentation, including:

- No massive specifications are needed. Issues like conformance to codes and other standards can simply be placed on the drawings and may very well have already been included under the general conditions of the overall performance contract, which was negotiated and signed before the design process even began.
- Make and model numbers of the installed equipment to go right on the drawings. In addition, the drawings can show great detail, for example indicating the actual equipment that will be installed. In fact, most major equipment manufacturers will provide CAD images of their equipment, which can be placed right on the drawings so that the project can be designed in great detail, as opposed to the more or less “generic” designs that are more characteristic of a design-bid process. In addition, such things as the actual control diagram for a piece of equipment (say a chiller or a boiler) can be incorporated right into the digital control drawings, and show the actual interface wiring (such as terminal block locations and images) rather than just showing “generic” interface “details” as many controls vendors are otherwise apt to provide by default.
- Finally, and this can be of great value, the design drawings in a design-build project are essentially the shop drawing, and, potentially, become the as-builts as well. A well thought-out design-build project will have sufficient detail in the design drawings, so that

they are virtually equivalent to shop drawings. And, assuming that the project is well planned, there should be no change orders and very few additions to these drawings to make them accurately portray the as-built conditions. Which provides the owner with a far superior construction record than more conventional means of doing design and construction.

The design deliverables in a design-build project should include the following:

- Mechanical plans
- Electrical plans
- Structural plans
- Control system plans, including point-to-point wiring diagrams and images of the terminal blocks for all devices being installed, and even to-scale building and equipment plan views that show the actual physical location of all control interface locations and control devices (so the maintenance guys don't have to search for where that differential-pressure transducer was located in the chilled water piping for the variable flow conversion!).
- Key calculations for equipment, piping, duct, etc. sizing and selection
- Key equipment submittals, which should be virtually unchanged from the documentation provided in the energy audit report previously provided

While the building owner surrenders significant control over the design process to the performance contractor, the owner should take their responsibility in the design-review process seriously and engage assistance if needed.

A small caveat here is that traditional plans-and-specs, design-bid consulting engineers would generally be the wrong people to ask for help in reviewing a set of design documents generated as part of a design-build project. This is because the vast majority of traditional consultants have little or no design-build experience and will insist that the simplified plans conform to their notion of what a design-bid

set of plans should look like. We have seen owners attempt to do this, and it has always resulted in considerable conflict and wasted time and energy. If you don't understand this paragraph, then you need help all the more. Call us and we'll explain and help you get on the right track

CONSTRUCTION AND INSTALLATION

While the owner should intend to make excellent use of the performance contractor to oversee and coordinate the construction and installation activity, the owner should not abdicate his role in this regard. We suggest the following:

- The owner should have a construction manager for the project, to watch the farm by means of observing construction and having regular progress meetings with the performance contractor.
- Standard of quality for the installation should be identified in the overall performance contract (as mentioned previously) or incorporated onto the design documents. Given the fact that a significant portion of the work may be subcontracted, it may actually be important to have a fair amount of information on the design documents so as to instruct a subcontractor who is not privy to the overall performance contract. Owners should not be afraid to enforce the standards of quality in code-related requirements as the owner will be "stuck" with the results of the project once the performance contractor departs. This is another reason why the owner's expectations as regards to the quality and brands of equipment and the quality of installation work should be established very early in the process, prior to the performance of the investment-grade audit by the performance contractor, so that the performance contractor's estimates of cost for various retrofit work can be based on an appropriate level of quality and not "low-balled" in order to make the project look financially attractive.
- Submittals for all materials and equipment, and shop drawings where appropriate should be provided by the performance contrac-

tor and/or their subcontractors. One of the problems that we have frequently encountered in the field is the fact that the subcontractors are kept at arm's length by the performance contractor and are not privy to the overall performance contract. The subcontractors therefore bid their work to a different standard from that which the owner expects. This has caused considerable grief on many projects in which we have been engaged (and resulted in a \$90,000,000 lawsuit between a West Coast school district and an East Coast performance contractor).

- A work schedule should be developed by the performance contractor and approved by the owner and all outages and disturbances to building operations must absolutely be coordinated between the performance contractor and the owners, project manager or construction manager.
- Installation, operations and maintenance manuals (IOMs) and two copies of all digital control software (particularly operating system and graphics generation software) should be provided.
- As-builts on all work should be provided, especially for control work

A rather detailed commissioning procedure should be used including, at a minimum:

- the operation of each piece of equipment should be demonstrated
- every digital control point should be tested and logged
- all control functions should be demonstrated (i.e. does the variable speed drive on a pump or fan actually vary its speed over time?)
- the owner's staff should be trained on the project
- a six-month follow up on controls calibration should be included; in fact, many owners insist on a six-month and a twelve-month in order to cover all seasons of the year.

We cannot overemphasize the importance of managing the design and installation process. We have found that troubled performance contracts are most often a result of insufficient rigor employed during the energy audit phase (see Chapters 5, 6 and 7) or of sloppy and poorly documented design, installation, and commissioning of the retrofit work. While the owner hands over the execution of the design phase of the work to the performance contractor, a building owner would be very unwise to not oversee and manage this phase in significant detail.

Chapter 9

Case Histories—

Where Do They Go Wrong?

INTRODUCTION

It has often been said that the “rubber hits the road,” in Demand Side Management (DSM) and Energy Services projects, at the point of measuring the project’s actual savings. In the world of DSM, this is important because the various State Public Utility Commissions must be assured that the incentives paid to utility companies are justified by actual demand and consumption reductions, and that those reductions will continue to occur over the life of the project. In the world of Energy Services, building owners need to know that the lease (or other) payments they make are offset by reductions in energy use and cost.

This chapter presents evaluations of two similar energy retrofit projects, both of which were done on a financed and guaranteed-savings basis. In one case the project was an unqualified success. In the other case it was a complete failure. The chapter describes the projects and their implementation methodologies, documents the projects’ performance, and makes recommendations regarding the selection of an ESCo and project implementation practices.

PROJECT NO. 1... A SUCCESS

Description of Project No. 1

This project was the retrofit of a county administration building and courthouse complex. The administration building was built in the late 60’s and is relatively modern in terms of its building construction, HVAC, and lighting systems. The courthouse building, by contrast, was built in the 1920’s and shows its age in terms of its construction, the wide

variety and age of its HVAC systems and the wide variety and age of its lighting systems. Each building was separately supplied with electricity and both buildings shared common central cooling and heating plant.

Through a competitive proposal process, the county chose a team to implement the project. This team consisted of a prime contractor (who was actually a local mechanical service contractor), a consulting engineer, and a financier. The steps to project implementation included the following:

- the completion of a very rigorous energy retrofit feasibility study including computer simulation of the entire facility to within 5% of its actual utility company invoices, performed collaboratively by the consulting engineer, the prime contractor and the owner's staff
- detailed review of the feasibility study by the owner, along with owner participation in selecting the final package of retrofit work to be performed—to suit their financial criteria, building maintenance and repair concerns, and other needs
- negotiation of a final turnkey retrofit contract
- completion of detailed final design, including such detail as point-to-point control wiring diagrams
- installation
- start-up and debugging of the project and training of owner's staff

The ultimate project implemented include the following features:

- the installation of an energy management computer for time-scheduling of virtually all HVAC equipment
- major modifications to the majority of the air handling systems in the two buildings including direct digital controls, conversion to variable air volume and the addition of outside air economizers on systems not so equipped
- extensive lighting fixture retrofit

Results of Project No. 1

The parties to this contract chose an avoided cost measurement methodology generally referred to at the time as “stipulated calculations”—now known as Option A under the IPMVP. In this methodology a series of formulas are developed which utilize energy factors which are agreed to by stipulation by both parties. The formulas also contain variables, such as equipment run-time and fluid temperatures, which are monitored and recorded by the building automation system. These formulas are embodied in an automated spreadsheet which is used on a periodic basis by the energy services contractor and the owner (both parties possess the spreadsheet) to account for the avoided cost produced by the project. In addition, as a control mechanism, our firm was asked to prepare monthly cost avoidance reports utilizing a comparison of monthly utility bills. (See comments in the Chapter 14 on software for Option C M&V regarding this expectation of most building owners.) In this mechanism the units of energy used during the pre retrofit base period are compared to the units of energy consumed after the retrofit is complete, and the difference in energy units is multiplied by (in this case) the average unit cost of each type of energy consumed. These reports were generated on ERA’s proprietary Energy Accounting Report System, which is described in the *Energy Engineering* annual “Directory of Software for Energy Managers and Engineers.”

As can be seen in Figure 9-1, the electrical use and natural gas use for the building complex was significantly reduced following the retrofit, when compared to the prior “base” period. As can be seen in Figure 9-2, which shows 12-month-long moving window totals, the long term trends in energy use are clearly down. (We frequently utilize 12-month-long totals to neutralize seasonal effects in the data so trends can be more easily observed.)

PROJECT NO. 2... A FAILURE

Description of Project No. 2

The second case study project was a retrofit of a full service community hospital, also located in California. Similar to the administration building and courthouse complex, this facility was constructed in a multitude of projects spanning a number of decades. While fairly modern, this hospital possessed a wide variety of HVAC and lighting systems

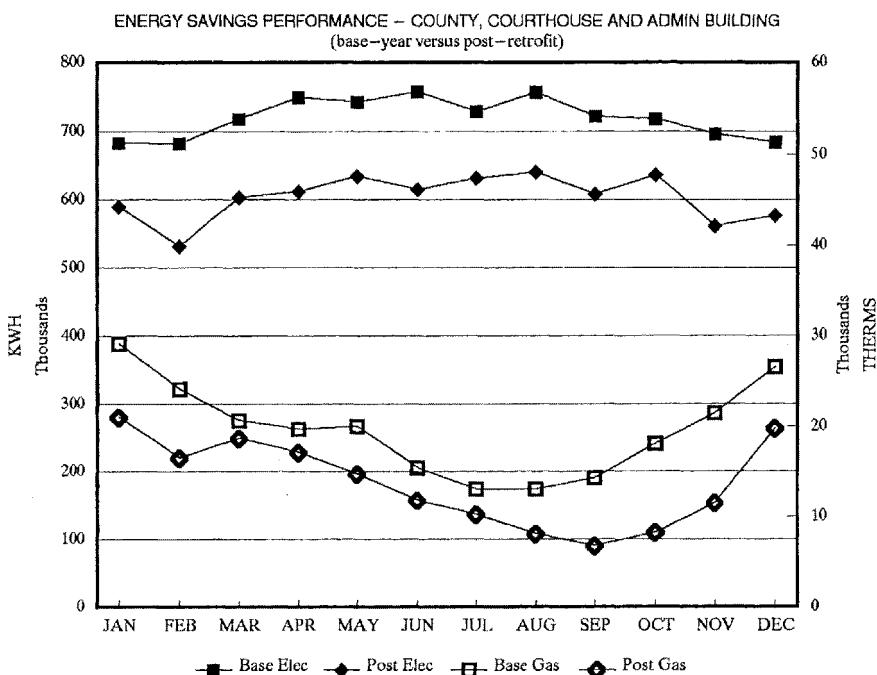


Figure 9-1.

and, notably, had three separate central chilled water cooling systems prior to its retrofit.

The implementation steps used for this project were significantly different than that of the first project described herein. Specifically, the steps included the following:

- a preliminary assessment and outline proposal from the contractor (a large, nationally recognized controls manufacturer)
- performance of a cursory “energy audit” by the vendor’s sales engineering staff, including minimal documentation
- preparation and presentation of a final proposal by the vendor
- contract negotiations and contract execution
- implementation of the project including minimal design documentation

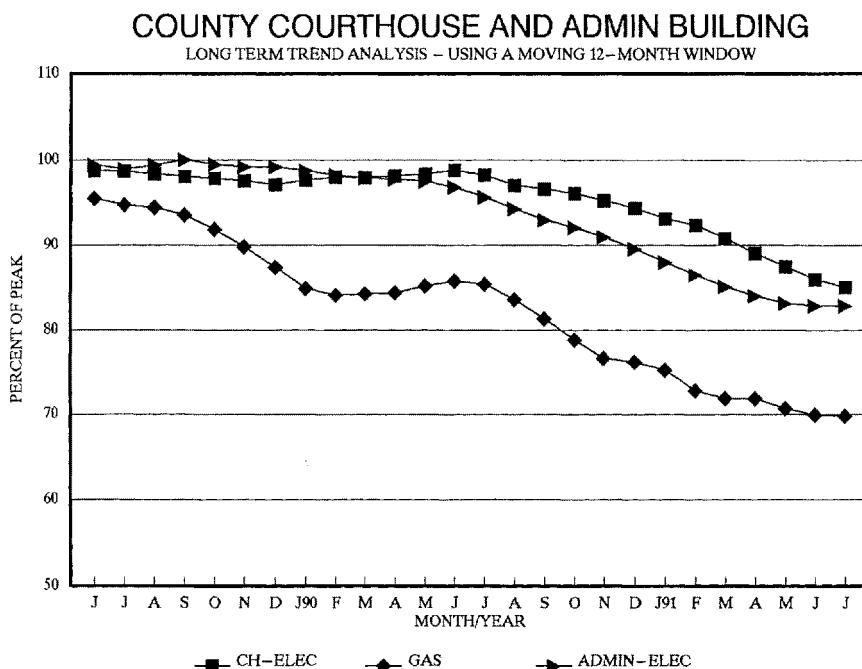


Figure 9-2.

The scope of construction for this particular project consisted of two basic components. The principle component was the installation of a new head-end computer on the existing building automation system. This computer was to provide automated scheduling of all equipment along with optimized control of chillers and their auxiliaries and optimized reset of the supply air temperatures of the majority of the air handling units. The project also incorporated field hardware necessary to provide the automated supply air temperature reset. The second component of the project was the integration of the existing stand-alone chilled water systems. This work included interconnecting piping and the provision of automated shut-off valving for the various chillers.

Results of Project No. 2

As can be seen in Figure 9-3, no noticeable change has occurred in the facility's use of electrical energy following the project implementation. In addition, Figure 9-4 (which again shows 12-month-long moving window totals) clearly demonstrates that the long term trends in energy use are also unchanged since the project was implemented.

No natural gas savings was estimated for this project and therefore no natural gas data is presented herein.

Analysis of Project No. 2

As a result of its non-performance, a detailed audit of this entire project was conducted and produced a wide variety of observations, as described in the following:

1. The original energy "audit" identified savings of approximately \$150,000.00 per year. Unfortunately, this audit was an "audit" in name only and, when examined in detail, it was revealed that little, if any, factual information formed the basis for the savings calculations, and that:
 - the calculations were incorrectly performed in that incorrect units were used in formulas (e.g., degrees Fahrenheit versus enthalpy in Btu per pound of dry air, resulting in a fourfold mathematical magnification of the true potential savings)

ENERGY SAVINGS PERFORMANCE – VALLEY HOSPITAL

(base-year versus post-retrofit)

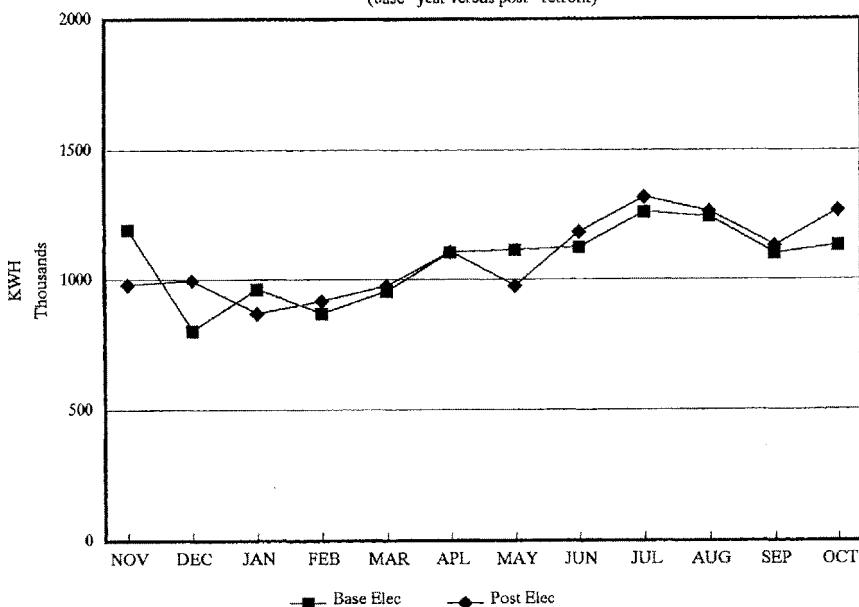


Figure 9-3.

- savings were double counted (e.g., cooling energy savings were counted at the air handling units and again at the chillers!)
- values in the formulas such as air handling unit airflows in cubic feet per minute (cfm) appeared to have been guesses, as they did not correlate in any fashion at all to the airflow rates listed in the as-built drawings. (e.g., a 30,000 CFM guess, versus 10,000 CFM from as-builts)

Investigation indicated that no actual field measurements or detailed survey work had been performed. In addition, even the simple formulas that were used for estimating savings were misused. Formulas intended for calculating the savings from supply air reset on double duct HVAC systems were used for single zone, terminal reheat, and high pressure induction systems.

In short, the engineering feasibility study, or “energy audit,” which was performed by the vendor, was little more than a marketing ploy used to make the customer feel comfortable and thereby close the sale.

VALLEY HOSPITAL

LONG TERM TREND ANALYSIS – USING A MOVING 12-MONTH WINDOW

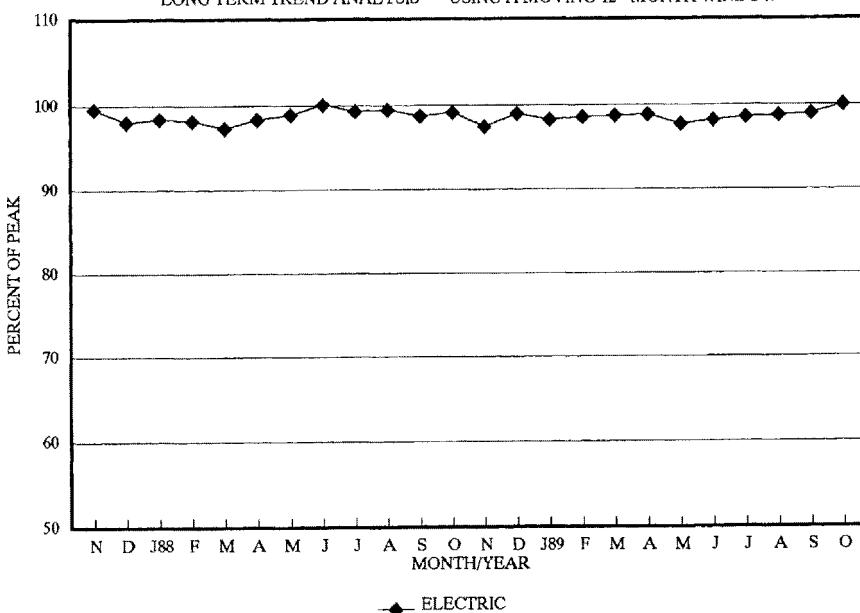


Figure 9-4.

2. As the retrofit contract provided for a guarantee of savings, the contractor agreed to provide monthly audit reports which would document the avoided cost produced by the project. These reports provided simple tabulations of numbers which purported to show that the energy savings guarantee was being met. However, none of the formulas used in these audit reports were ever documented to the customer, and they apparently embody the same erroneous formulas used in the original estimates of savings. Furthermore, the formulas were to employ variables such as the actual supply air temperatures at air handling units as reset by the automatic controls, and monitored by the building automation system. However, the audit reports simply show the same constant supply air temperature which was assumed for the original savings calculations. As a result, the monthly "audit" reports were little more than the original savings calculations presented in a new format.
3. Not only were the original estimates of savings erroneously wildly optimistic and the audit reports bogus, but further investigation of the modified building automation system ultimately revealed that, in fact, it was not working. While a new head-end computer was indeed installed, and the optimization software installed in this computer, the system had sufficient difficulties in its operation that the installing vendor ultimately removed the software and left the computer in place. This left the system in virtually the same condition it was prior to the retrofit. That is, reset of supply air temperatures, starting and stopping of chillers and pumps, etc. all had to be initiated by the system operators, as opposed to being automatic.
4. Because a detailed engineering feasibility study was not conducted and therefore a detailed technical plan for the project implementation was also not created, the project evidently went straight from sales to installation without really passing through a design stage. The results of this omission, for example, were such things as two air handling systems (one serving an interior zone while the other serves an exterior zone) having their supply air temperatures reset by means of a single control point from the building automation system! Clearly, the heating and cooling needs of these two spaces vary greatly and it would therefore be impossible to optimize their supply air temperatures simultaneously. In the course of the audit

of the project, no documentation whatsoever was found for the modifications to the building automation system. Construction documentation was discovered for the modifications to the chilled water piping, valves, etc. However, this documentation was found to be significantly inaccurate when compared to the actual installation.

SOME OTHER PROJECTS

In our work we have seen scenarios ranging from the best to the worst, in all their contrasting “glory” (or “gory,” as the case may be). Unfortunately, good results or bad are not restricted to any of the “models” of ESCo’s (as described in Chapter 2). Smaller, local contractors can turn out marvelous projects, and large, nationally prominent firms can produce projects which are truly despicable (while the “conventional” wisdom would seem to suggest that the opposite is the expected outcome). This range of possibilities is conveyed in Table 2 which summarizes a variety of real projects which we have been involved in directly, either as the project engineers or as the expert witness investigating the reasons for non-performance.

GREED—THE GREAT DESTROYER

A potentially fatal flaw in a performance contracting deal is greed. Greed on the part of the ESCo. And greed on the part of the owner. Yes, either of these can be fatal. In business school they teach about the “greater fool” syndrome. This is what occurred in the late 1920’s (for one instance) where the stock market went crazy because stock buyers bid up the price of stocks to unbelievable levels. How can this happen? Well, as the instruction goes, it doesn’t make any difference what you pay for a stock, as long as you can find someone who is an “even greater fool” than yourself to sell the stock to. Where owners have gone astray here is to focus almost exclusively on the “financial” side of an ESCo’s offering. This is an easy trap to fall into when the whole reason for hiring the ESCo is that your organization (county government, local school board, community college, etc.) doesn’t have the capital funds to pay for the project in house and your organization has locked themselves into the

Table 9-1. Summary of a Case Studies Project

Project Character- istics		Type of Facility					
		County Offices	Private Hospital	Private Hospital	County Buildings	County Buildings	County Buildings
Results	Success	Success	Failure	Failure	Aborted	Qualified Success	Mixed
Type ESCo	Contractor	Mfgr.	Mfgr.	Broker	Broker	Contractor	Broker
Procured by	RFP/Negot.	Negot.	Negot.	RFP/Negot.	RFP	Negot.	RFP/Negot.
Engineering	Excellent	V. Good	Dismal	Dismal	N/A	Mixed	Mixed
Installation	Good	Good	Incomplete	N/A	N/A	Excellent	N/A
Monitoring & Maintenance	Good	Good	Fraudulent	N/A	N/A	Good	N/A
Guarantee?	Yes	Yes	Yes	Yes	Yes (required in RFP)	No	Yes
Comments		1	2	3	4	5	

1. No savings produced at all after 1.5 years. ESCo submitted fraudulent monitoring reports. Owner sued ESCo.
2. Feasibility study was fraudulent. Owner sued ESCo. ESCo subsequently went out of business.
3. Following pre-proposal walk through where it was discovered that the facilities' HVAC systems were virtually non-functional and in need of major restoration only one ESCo submitted a proposal—which was bogus. Owner declared the proposal non-responsive and terminated program. Owner later sole-source negotiated a lighting retrofit project only.
4. Feasibility study was erroneously optimistic. Savings had to be verified for utility rebate. Owner ultimately satisfied with well planned & implemented project, even though savings were less than anticipated.
5. ESCo hired two engineering firms to perform the feasibility studies for the facilities. One was very well done, the other was dismal. Owner terminated contract at completion of study due to change in ownership.

mindless procurement methodology of awarding contracts based on “low bid.” First of all, almost nowhere is the concept of “you get what you pay for” more true than in the world of retrofit. Retrofit work cannot be defined with the same ease as new construction, and when well done, the least costly retrofit is a product of the engineer and the installer working in intimate collaboration—meaning that it’s the product of a design/build retrofit process, which is virtually impossible to competitively bid (and you’re foolish if you think it can be!). Secondly, just as design/build retrofit is virtually impossible to competitively bid, the “savings” to be produced in a performance contract also cannot practically be competitively bid for a couple of reasons. These reasons include the fact that a good honest estimate of potential savings cannot be made until a detailed feasibility study has been performed. Such a study is expensive to complete and no ESCo, no matter what they may claim, can afford to incur this cost on a speculative basis prior to the signing of a contract (see Chapter 3). Also, as discussed in Chapter 4, accounting for the savings actually produced by an energy retrofit project cannot be established with absolute certainty—only with a fairly high degree of confidence. As a result, the inability to document savings with absolute precision means that someone who has sold you a ridiculously high estimate of savings, can easily perpetuate your role of the “greater fool” by selling you a similarly bogus monitoring report.

The fourth case study in Table 9-1 is a case in point. This County chose their ESCo’s based almost entirely upon the ESCo’s projection of savings following a very cursory survey of the 50 or so facilities to be included in the program. In fact, the County even chided proposers who presented reasonable, but low, estimates of savings for trying to “cheat” the County! The County’s program manager (a contract employee) was compensated based in part on the projected savings from the program (the bigger the estimate, the bigger his compensation), so he was an active promoter of big savings numbers. Combined, these forces allowed an unscrupulous ESCo to generate wildly optimistic estimates of savings during the sales process and be welcomed by the buyer in doing so! Fortunately for this owner, they realized their folly fairly early on (though not before paying the ESCo nearly a million dollars for “services” provided) and terminated the relationship before it got completely out of hand. The third case study was similarly unfortunate in that the owner bought a wildly optimistic estimate of savings, but didn’t discover their folly until the project was a year and a half down the road

from completion and somehow the meter just didn't seem to be spinning any slower (even though the ESCo was certifying monthly that it was indeed!).

A final insight into this potentially insidious aspect of performance contracting, is that ESCo's whose organizations are dominated by the marketing side of the house tend to be the "guilty" parties. What happens in such organizations is that the sales folks come up with outlandish preliminary projections of savings during the sales process and then, during the detailed feasibility study phase of the project (if there even is one) the engineering side of the house is essentially given a mandate to make the sales "lies" into "truth" by finding (read "creating") the savings which justified the sale in the first place. This may seem unbelievable, but it's true—as evidenced by the case studies exemplified herein. Unfortunately, it seems that once an organization allows themselves to start down the crooked path, it is seldom possible to make a "course correction" later on (short of calling in the lawyers—and the expert witness).

CONCLUSIONS

The two projects described in some detail in this chapter are nominally similar. They were both financed and guaranteed, turn-key energy retrofit projects. The difference between the two projects is the nature of the participants and the character of their approach to project implementation. To help our clients avoid the pitfalls chronicled above, our firm has established what we believe to be a good set of fundamental ground rules for the implementation of Energy Services or DSM projects, as follows:

1. Selecting an ESCo. The firm or team to do the project should be selected on the basis of their experience and qualifications, not just the financial underpinnings of the firm, optimistic (and admittedly enticing) savings projections, or a "rosy" sounding guarantee. Every ethical ESCo we are aware of is willing to commit up front to a precise definition of project costs, open-book job-cost accounting and the cost of money (the interest rate) in return for being selected based on qualifications, rather than having to prepare a very costly technical and financial proposal

2. **Investment grade energy audit.** A detailed feasibility study is always required. There is simply no substitute for time spent in the field investigating systems and equipment, time spent in analysis of the building and its energy using systems and time spent performing detailed calculations of the potential energy savings that might be achieved by implementing certain energy conservation measures. Generally speaking, computer simulation or other means to achieve an energy balance, i.e., a totalization of all the sources and uses of energy in the facility, is essential. In addition, estimates of savings should “spring-board” out of the comprehensive energy use model so as to prevent double counting or wildly optimistic estimates of savings. As a specific example, if a building only spent \$60,000 per year operating its cooling equipment, an estimated annual savings of \$50,000 for this function is probably not reasonable, even if the total annual energy bill is \$500,000 or more. Each “piece of the pie” must be looked at individually instead of always being considered as a part of the “total pie.” Finally, the engineering feasibility study, its source data, and the bulk of the assumptions and calculations, should be documented for review by all parties.
3. **Third party, complete contract.** The energy services agreement (or performance contract) should start with a document developed by a third party and all terms equitably negotiated—as opposed to defaulting to the “standard” contract offered by (or insisted upon) by the ESCo. Among other things, the intended energy conservation work should be identified by means of detailed scopes of construction work so that the installing company as well as the buyer can have a “yard stick” by which to measure whether or not the project has actually been implemented.
4. **Construction documents.** Extensive construction documentation should be developed, both to guide the installing contractor’s craftsmen, but also for the owner to see and concur with the detailed installation work planned, and to use as a troubleshooting tool once the work is complete and/or the contract term has run out.
5. **Construction standards and management.** The actual physical implementation of the work should be accomplished per a pretty

rigorous set of standards that are embodied in the energy services agreement, and the process should be actively managed by the owner's staff.

6. Commissioning. Otherwise known as "verification." The entire project should be started up and demonstrated to the satisfaction of the owner's representative that it all works—and works correctly. The project must have the potential to save energy before it can actually achieve energy savings.
7. Post-retrofit monitoring of performance. Otherwise known as "measurement." Whatever means is agreed to by the parties for accounting for the avoided costs produced by the project, these means should be clearly defined, well-documented and implemented in such a way that both parties can track avoided cost when starting with the same periodically measured source data (unit costs of energy, system operating parameters, equipment run times, etc.).

There is great pressure from the various state legislatures and public utilities commissions to implement turn-key energy retrofit projects. Unfortunately a number of vendor firms are taking advantage of this business opportunity even though they are not truly competent in the field (the recent largest bankruptcy in the history of the U.S. being but one example). Facility owners and utility companies should avoid being mesmerized by glossy corporate images and "no risk" guarantees. Such purchasers should ask themselves the question: "Do we want a guarantee... or do we want a project that works?"

Chapter 10

Introduction to Measurement And Verification

Steve Kromer, Teton Energy Partners

FUNDAMENTALS—QUANTIFYING THE RESULTS OF ENERGY PROJECTS

If you are involved in performance contracts you will eventually have to answer the question, “was the project successful?” To some people, this is the same as asking, “did my utility bill go down?” To others, the relevant question is “ did the project perform as specified”? Or perhaps an owner will want to know, “did the guaranteed savings actually occur?” For all of these questions, Measurement and Verification (M&V) is the language and discipline that can provide the answers. In fact, M&V is really a way of addressing both the engineering and legal issues in performance contracts so that two parties can mutually agree on the results of energy efficiency investments.

In the wholesale and retail energy markets, buyers and sellers of energy “settle” their accounts on a regular basis. The settlement process is usually straightforward, but can involve complications that make it non-trivial. In performance contracts the settlement of “savings” is rarely, if ever, non-trivial.

What makes the settlement of performance contracts and M&V so difficult?

Things **change**.

When energy suppliers settle accounts, they need only hook up a meter to the generation device and watch the meter spin. When a customer hooks up to the grid another meter reads how much they have consumed. The energy user’s settlement is straightforward (unless the meter multiplier is wrong). The precision of the measurement is regu-

lated by state authorities and is rarely questioned.

But there is a critical problem for those whose responsibility it is to quantify energy savings as opposed to energy delivered—**savings** cannot be measured directly.

Energy savings settlement requires two measurements:

- the usage before the project is implemented—**the baseline**, and
- the usage after the project is completed—**post-project energy usage**.

The post-project usage measurement is provided by the spinning meters above. It is usually straightforward, if not inexpensive, to measure the performance of any energy-using system. There may be some question about accuracy of measurements for thermal loads, temperatures and end-uses but conceptually it is the same as for any metered load. So where and why is **change** (volatility) a problem? The answer must lie in the baseline.

Consider the energy use profile in Figure 10-1, a scenario with little or no change.

Because there is little change (volatility) in the baseline, there is little uncertainty what the energy consumption would have been without the retrofit. A quick look tells us that the baseline was 2 units and the post-project usage was 1.5 units. Is there anyone who thinks the “savings” were other than 0.5 units? Good.

This example seems obvious, but it illustrates a fundamental concept. When there is little or no change in the baseline condition, and there is little or no change expected for the duration of the contract, M&V is trivial.

Now consider a world with change (volatility), as shown in Figure 10-2.

In the case where there is change (volatility), the parties involved must identify causes of the volatility, how much it contributes, and how to manage risks arising from the uncertainty of the quantity of savings.

This brings up another fundamental concept of M&V. The baseline often changes over the life of the project. How much it changes, and why it changes are the two main questions that M&V seeks to answer.

Let's go back to the analogy of the supply meter and the usage meter. The primary value derived from energy efficiency projects is the quantity of savings that result from the project. One way to think of M&V is as a Negawatt Meter for measuring the savings “generated.” The

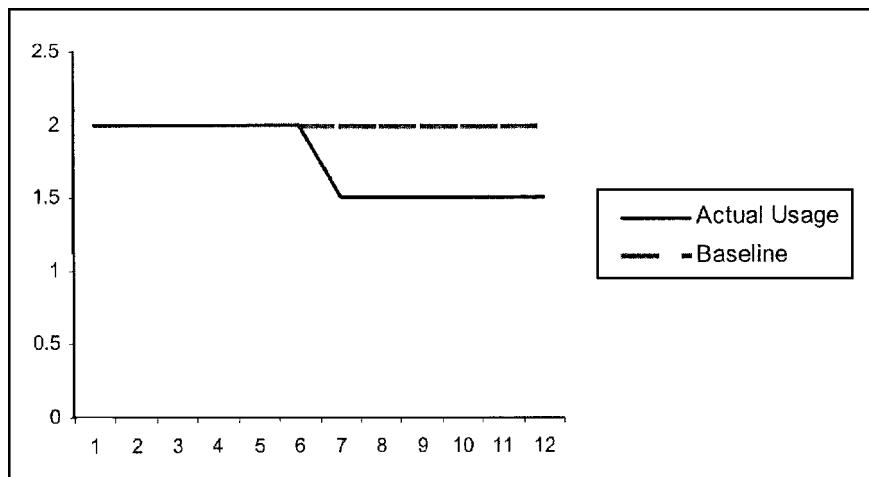


Figure 10-1.

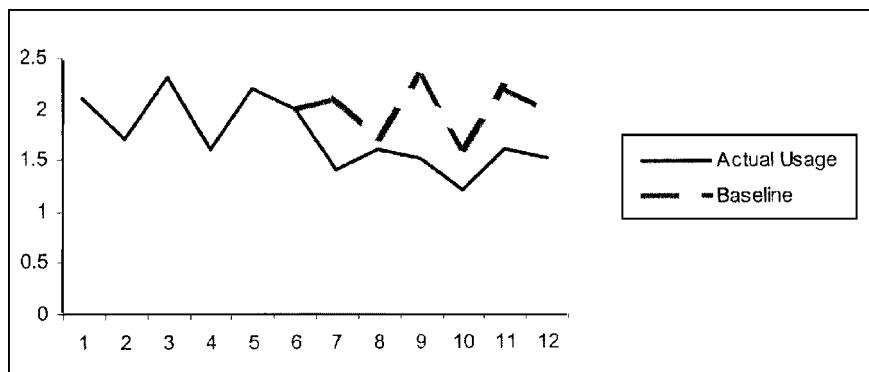


Figure 10-2.

M&V plan is the design for the Negawatt meter. It dictates what measurements will be taken and how the savings will be quantified. The M&V plan is different for every project because there are different causes of uncertainty and volatility in every project.

And what are some of the causes of uncertainty? Generally they fall into two categories, performance and operation. Performance metrics measure the “miles per gallon” of the energy-using equipment. Some typical examples are lumens/watt, kilowatts/ton. Operation metrics typically measure the duration or set points such as hours/day of lights, or temperature control settings. One can easily imagine how changes in

performance and operation might cause uncertainty in savings calculations. The performance contract must clearly assign responsibility for each type of risk. Once the risk is assigned, the M&V plan can be targeted to cost-effectively measure and manage those variables.

Example—An owner has two facilities. One is a warehouse that operates 24/7. The second is retail outlet that operates on variable schedules throughout the year. In a contract to install efficiency lighting in the warehouse, the M&V plan focuses on instantaneous before-and-after measurements. For the same retrofit (lighting efficiency) in the retail outlet the M&V plan includes measurement of operating hours to reduce the uncertainty in project payback. The same retrofit, lighting efficiency, has a different M&V plan depending on the type of facility and its operation.

Typically there are two parties in a performance contract, a facility owner and an energy service company (ESCO)

Owners typically invest in performance contracts in order to utilize off-balance sheet financing. The owner wants to know that the “savings” generated by the ESCo will materialize and the cost of operation will decline. The ESCO seeks to earn a return for their investment, their technical contribution and the risks they take on. Like any financial transaction, if the owner wishes to shift risk to the ESCO, they should expect to pay for it. If the ESCO seeks to be free from operational risks, this should be reflected in their cost proposal.

The contract is the controlling document to delineate risk and rewards from energy project development. There are many terms and conditions in a contract, such as when the ESCo can get access to the facility, but the primary objective of the contract should be to clearly and consistently define what “savings” means in the context of a specific project, and which party will absorb the losses, or reap the benefits, should conditions change during the contract term. Since we now know that changes almost always occur over the life of a project, we can see how the M&V plan, by anticipating potential changes ahead of time, prepares both parties to quickly adjust and settle the savings over the course of the project.

Example—An ESCo performs a lighting retrofit. The project reduces 10 kW from the lighting load. The baseline hours of operation were 4000 hours per year. The “savings” were agreed to be 40,000 kWh per year. A year into the project the owner operates the facility twice as long. Are the “savings” now 80,000 kWh per year?

If you can get past this step, the rest is very easy.

FUNDAMENTALS OF PROJECT SAVINGS CALCULATIONS

Initial Assessment

When an engineer develops a project he has a concept of which existing conditions can be changed to generate savings. If the assessment/audit is done correctly the engineer will have performed measurements to support any assumptions about existing conditions. Measuring as part of an audit and measuring for M&V provide the justification for the project and the data to compare to post-retrofit results to quantify savings. While not every audit will include detailed metering, there are often opportunities to perform the metering at the audit stage and accomplish the M&V baseline at the same time. The audit/baseline is the most important step in the process because without it, you'll never be sure how much you've improved performance or operation.

Documenting Baseline

The challenge of M&V is that there is not one perfect M&V plan that fits all projects. Every project must be considered in terms of the contractual obligations of both parties. In our example above with the lighting retrofit, let's assume the owner intends to change the operation of the facility frequently during the term of the project. The owner might stipulate the operating hours for the purposes of making ESCO payments. The M&V plan would not call for detailed operating hours measurements and much time, effort and money could be saved.

On the other hand, if the ESCO is proposing a novel lighting control strategy that the owner considers risky, they might agree to perform detailed baseline monitoring to accurately document existing conditions. The M&V plan should reflect all contract terms and conditions.

Forecasting Future Volumetric Consumption

After the ESCO establishes the baseline, they can perform detailed calculations on the amount of energy (not dollars) that can be saved from various retrofits. The ESCO's engineer will typically use spreadsheets or computer programs to "model" the proposed project. The proposed project will require the engineer to input expected project performance and operational parameters which lead to savings. This is the core of the

M&V plan. The values that the engineer inputs into the model are the target values that the M&V plan will monitor. If a lighting savings project is based on replacing 100-Watt lamps with 60-Watt lamps, the M&V plan should confirm that the new lamps actually perform as specified.

MEASUREMENT

When to Measure?

The concepts of measurement and verification broadly cover all the methods of assessing savings in performance contracts. In many, if not most cases, the M&V plan will include physical measurements of loads or conditions, e.g. temperatures, within the target facility. However measurement is not always necessary. Physical measurement is justified only when the cost of performing the measurement is offset by some reduction in risk in the contract.

Example—A warehouse considers a lighting retrofit. All parties agree that the baseline lighting operation is 8760 hours a year. They agree on the type of existing lamps/ballasts and replacement lamps/ballasts. The parties agree that published performance data is sufficient for quantifying the performance of the lamps. In this case the M&V plan would not include physical measurements.

A more common example would be a chiller project where the operation and performance of the existing and replacement equipment is uncertain. The M&V plan in this case will involve physical measurement, but what?

What to measure?

Efficiency projects are based on changes to an existing system. They can change the existing system by changing the performance, by changing the operation, or by changing both. The M&V plan should be designed to verify the changes and account for continued performance over the term of the project. The plan should balance the cost of measurement against the value of reduced uncertainty. Any money spent on M&V that does not reduce uncertainty is wasted project value.

How long to measure?

The duration of measurement follows the same principal stated above; any measurement that does not reduce uncertainty is wasted

value. The M&V plan should consider the cost of continued measurement versus what is learned about the system. Stable loads require much shorter measurement periods than volatile loads. The value of measurement is derived solely through reduced uncertainty.

How much to spend?

There is only one way to assess the correct amount to spend on M&V and this requires that the owner have a position on the value of uncertainty. Just as in any financial transaction, low-risk investments pay lower returns. The right amount to spend on M&V can only be determined if the parties to the contract know how much risk they are willing to be exposed to, and they know the value of reducing/understanding that risk using measurements. The mathematical principles of optimization are beyond the scope of this book, but it bears repeating that unless you can attach a value to the measured information, it may not be worth collecting. Before you agree to an M&V plan, no matter which side of the deal you are on, make sure you know how you will use the measured data.

Note: The above paragraphs may seem to indicate that the author is against measurement in general. Nothing could be further from the truth. However, after years of engaging in debate about how much M&V is enough I've been troubled by the lack of a rational justification for the proper amount of project resources to spend on M&V. Merely quoting ranges (1-10%) for typical costs without justifying the expense is inappropriate.

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Chapter 11

M&V Documents

Steve Kromer, Teton Energy Partners

Assuming the previous chapters have convinced you that M&V is not a mysterious black art, but is in fact an interesting and useful topic, where do you go for more specific information? This chapter will introduce you to several documents, which were written specifically to address the needs of M&V users.

Why are there several documents, and how do they differ or overlap? That's a very good question. To answer it one must first understand a little about the motivations and goals of those who create protocols and guidelines. (Note: The author did time on each of the committees listed here. He was also the project manager for the FEMP M&V Guideline. He claims neither credit nor blame for the outcome of these efforts, but does believe that the following insights might prove useful in understanding how we got where we are today.) Ten years ago there were no industry documents for M&V. Now there are several. And to add to the confusion two of these documents came from one organization, the US DOE. And to add even more confusion, by the time this chapter is printed there may be even more documents. What is an M&V person to do? Consider the source(s).

This author contends that there are three main documents in M&V that each serve a different audience and purpose. The big three are:

IPMVP—Created by a committee seeking to reduce uncertainty in M&V energy efficiency investments. Currently managed by a non-profit business, IPMVP Inc.

FEMP—The US Department of Energy Federal Energy Management Program's M&V Protocol—Written to address the needs of a major market segment, the federal ESPC contracts.

ASHRAE 14-2002—Created to address the technical and transactional issues of energy savings contracts.

Some Detail and Perspective Follows

The IPMVP is, among other things, a hard name to remember. Don't feel bad if you mess it up. We tried to shorten the name to MVP but that simplified name hasn't yet taken hold. What is encouraging and most important about the IPMVP is that it grew from a grass-roots beginning to become the most widely adopted protocol. It was always a volunteer effort and frequently the scene for contentious debate. But throughout the process of creating three versions of the document, the IPMVP was, and still is, the people's protocol. If you see something in it that you don't like you are free and welcome to join a committee to make your opinions known. Along the way you will no doubt rub elbows with a community of concerned and earnest practitioners who are involved because they believe in the effort and believe in the future of energy efficiency and environmental initiatives.

The IPMVP documents were the result of broad involvement from an open committee structure. If you've written a document by committee you'll understand why the IPMVP has taken a couple revisions to work out the kinks. Earlier versions were bulky, disjointed and internally inconsistent. The current version MVP 2001 is clean, readable and effective.

So if IPMVP has improved so much, why is there still a FEMP-specific document? Because everything moves to its own rhythm. The FEMP SuperESPC program was years in the making. The first step required convincing the US Congress to authorize a new form of federal contracting. An almost unfathomable amount of work went into opening the door to ESPC in the government sector. Along the way the FEMP M&V Guideline was written specifically for performing M&V in federal contracts. Given the scope, complexity and relative rigidity of federal contracting this effort was appropriate at the time. And at the time FEMP M&V Guideline was first written, it provided a more user-friendly approach to M&V. In fact we called it the first "Application" of the IPMVP with the thought that other applications might be written to fill various needs. We on the IPMVP committee considered the multitude of applications that might arise from the framework of the IPMVP and wrote the following introduction.

From the Introduction to IPMVP

"The IPMVP is not intended to prescribe contractual terms between buyers and sellers of efficiency services, although it provides guidance on some of these issues. Once other contractual issues are decided, this document can help in the

selection of the measurement & verification (M&V) approach that best matches: i) project costs and savings magnitude, ii) technology-specific requirements, and iii) risk allocation between buyer and seller, i.e., which party is responsible for installed equipment performance and which party is responsible for achieving long term *energy savings*."

We further clarified our goals in section 3.5

From IPMVP Section 3.5

"The IPMVP is a framework of definitions and methods for assessing energy savings. The IPMVP framework was designed to allow users to develop an M&V plan for a specific project. The IPMVP was written to allow maximum flexibility in creating M&V plans that meet the needs of individual projects, but also adhere to the principles of accuracy, transparency and repeatability."

So if you are looking for the broadest guidance on M&V concepts, use the IPMVP. If you seek to understand how one, albeit very major, player interpreted IPMVP, look at the FEMP M&V Guidelines.

The last, and most recently released of the Big 3 M&V documents is ASHRAE 14-2002. It may be the most recently released, but its inception predates IPMVP and the FEMP Guideline. ASHRAE first formed a special committee to work on savings verification in 1993. The work to create 14-2002 proceeded at a typical ASHRAE pace, steady and measured. This is the norm for a consensus body with strict rules for developing and releasing technical documents. The resulting product is an engineers dream, detailed and arcane. Time and use will tell how much additional value 14-2002 brings to the industry. My guess is that every serious M&V practitioner will have at least one dog-eared copy of the 14-2002 in close proximity. However for programmatic and legal types 14-2002 will be a document that is considered a useful supplement to IPMVP or another overarching framework document.

I hope this discussion provides some perspective on several of the major M&V documents that you might come across. All of them have a place in the industry and all were created by dedicated individuals who labored long and hard to bring you answers on M&V. None is perfect, but each was crafted to assist in the goal of standardizing and the process of assessing energy savings.

Before I finish, I'd like to clarify one small point. Early in my M&V career I was asked the pointed question, "Is it possible to measure savings?" Like many, I initially took the question to be a mere teaser and a semantic trick. But after years of working in this industry I believe that

this is the most important question that can be asked. An M&V book, protocol or lecture is not complete without a vetting of the word “savings.” In my travels and lectures I’ve often asked the audience what constitutes savings under various contexts, and I have never found complete agreement. Given that performance contracts are agreements between two parties related to the creation of value through the reduction of energy usage it is imperative that the two parties agree on what constitutes “savings” for their project. Those who assume that such agreement is trivial do so at their peril. More misunderstanding and contention arises from the (lack of) definition of savings than from any other issue. For that reason, to state that you can measure something (savings) that you can’t even define is foolishness indeed.

One approach I have taken to reduce the harm is to attempt to erase the words “measured savings” wherever they occur. While there are many who agree with me on this, it has proven harder than expected. There are many others whose careers are defined by their ability to “measure savings.” Rather than continue to attempt to eradicate the words, allow me to encourage you to consider these steps when you are defining savings for your projects.

1. Both parties agree on the initial conditions for the target project (energy usage, equipment type and condition, controls, environmental conditions)
2. Both parties agree on the project scope and the related performance assumptions. Preferably the ESCo will present a detailed savings calculation model.
3. Both parties agree on the how changes to the project baseline or post-project conditions will propagate to the “savings” quantity. How will “savings” change if the hours of operation change during the contract, If the weather changes, or if the facility grows or shrinks in size?
4. Assign responsibility for any possible changes to one of the parties to the contract.
5. Agree that “savings” is a contractual quantity that is a combination of measured values and agreements on who bears responsibility for the inevitable changes that will occur over the course of the project.

Chapter 12

M&V Options and Project-specific Examples

The purpose of this chapter is to discuss and explain the measurement and verification options provided for within the IPMVP and to show somewhat-real-world examples of how each of the options might be implemented.

M&V OPTIONS

As we have seen in earlier chapters, there are four different “options” that might be employed, either universally or in combination, to account for the energy savings of a performance contract. For the purpose of this chapter, we will use the options as defined in the 1997 IPMVP, which is still in favor and in use by many, and is a good “middle ground” upon which to base the discussions in this book. In addition, the 1997 IPMVP finds favor in some corners as it allows a more simplistic approach to M&V than its successor. We note that this same bias is shared with FEMP, which also allows a more simplistic approach (see “Detailed Guidelines for FEMP M&V Option A,” 5/29/2002—www.eren.doe.gov/femp/financing/espcl/pdfs/detailed_guidelines_final.pdf).

The options we will discuss in the following are:

- Option A (retrofit isolation, with measured performance, and stipulated operation)
- Option B (retrofit isolation, with measured performance, and measured operation)
- Option C (whole-building or utility-bill comparison)
- Option D (calibrated simulation—a pseudo-option)

We will use the authors' descriptions, rather than fancy names, in order to keep close to the concepts involved.

In truth, this chapter provides project-specific examples for Options A and B, with discussion only for Options C and D. Option C is covered in considerable detail in its own chapter, and Option D is in essence a specialty activity which warrants addressing in depth separately—as the author has done in his 2000 publication entitled “Computerized Building Energy Simulation” by The Fairmont Press.

Furthermore, as mentioned in more detail below, we will address the concept of valuing energy savings, something which the IPMVP (1997 and 2000 MVP) have yet to be brave enough to undertake (a major shortcoming in the author's opinion).

PROJECT-SPECIFIC EXAMPLES

In order to provide some project-specific examples, which are a particularly helpful portion of the two day seminar, we have created an example project. The example project is based on a real building in the Silicon Valley region of the San Francisco Bay Area, which is a medium-sized R & D, manufacturing and office facility used for the microelectronics business. The project is a comprehensive building energy retrofit consisting of lighting fixture retrofit, a variable air volume retrofit and the installation of a new chiller plant with variable-flow chilled water and new cooling towers. The building is assumed to have a single large air handling unit serving the entire facility, (which is actually not all that uncommon) as well as 277-volt dedicated lighting panels on each floor of the premises, (or a dedicated 277-volt bus riser) and the chiller plant is assumed to consist of two chillers.

OPTION A FOR LIGHTING

For this example we would use method LE-A-01 as defined in Appendix II of the IPMVP (see Table 12-1). This method provides no metering or direct measurements in the field, and consists of the following.

1. We will count or inventory the actual fixtures retrofitted, by type.

Table 12-1. Summary of M&V Methods by Technology and M&V Approach.

Method & Reference	Technology	Option	Approach
LE-A-01, Chapter 5	Lighting Efficiency	Option A	No metering
LE-A-02, Chapter 5	Lighting Efficiency	Option A	Spot metering of fixture wattage
LE-B-01, Chapter 10	Lighting Efficiency	Option B	Continuous metering of operating hours
LE-B-02, Chapter 11	Lighting Efficiency	Option B	Continuous metering of lighting circuits
LE-C-01, Chapter 18	Lighting Efficiency	Option C	Utility billing analysis
LC-A-01, Chapter 6	Lighting Controls	Option A	No metering
LC-A-02, Chapter 6	Lighting Controls	Option A	Spot metering of fixture wattages
LC-B-01, Chapter 12	Lighting Controls	Option B	Continuous metering of operating hours
LC-B-02, Chapter 13	Lighting Controls	Option B	Continuous metering of lighting circuits
CLM-A-01, Chapter 7	Constant Load Motors	Option A	Spot metering of motor kW

(Continued)

Table 12-1 (Cont'd). Summary of M&V Methods by Technology and M&V Approach.

CLM-C-01, Chapter 18	Constant Load Motors	Option C	Utility billing analysis
VSD-A-01, Chapter 8	VSD Retrofit	Option A	Spot metering of motor kW
VSD-B-01, Chapter 15	VSD Retrofit	Option B	Continuous metering of motor kW, speed frequency, or controlling variables
VSD-C-01, Chapter 18	VSD Retrofit	Option C	Utility billing analysis
CH-A-01, Chapter 9	Chiller Retrofit	Option A	No metering
CH-A-02, Chapter 9	Chiller Retrofit	Option A	Verification of chiller kW/ton
CH-B-01, Chapter 16	Chiller Retrofit	Option B	Continuous metering of new chiller
CH-B-02, Chapter 16	Chiller Retrofit	Option B	Continuous metering of new chiller and cooling load
CH-C-01, Chapter 18	Chiller Retrofit	Option C	Utility billing analysis
CH-C-02, Chapter 19	Chiller Retrofit	Option C	Computer simulation
GVL-B-01, Chapter 17	Generic Variable Load Project	Option B	Continuous metering of end-use energy use
GVL-C-01, Chapter 18	Generic Variable Load Project	Option C	Utility billing analysis
GVL-C-02, Chapter 19	Generic Variable Load Project	Option C	Computer simulation

Note: Above table excerpted from 1997 IPMVP, Appendix II

2. The two parties will stipulate the before and after watts drawn by each fixture.
3. Both parties will stipulate the operating hours of the lighting fixtures.
4. We will then calculate units of energy saved (kWh) from the difference in the before and after fixture watts multiplied by the stipulated operating hours for each type of fixture.
5. We will calculate the cost avoidance by multiplying the units of energy saved multiplied times a unit cost.

Looking at Table 12-2 we see one of many tables which is part of the procedures manual for the standard performance contracting program employed by the three largest investor-owned utilities in California in recent years. What this table illustrates is a mechanism for two parties to adopt, by means of stipulation, a third-party-established set of values for pre and post-retrofit fixture wattages. For example, if we were to take an existing fixture of code F43EE (the fourth fixture in the left-most column) and retrofit it to a fixture code F43ILL-R (which is the ninth fixture in the left-most column) the two parties would be able to agree that the pre-retrofit fixture wattage is 115.0, while the post-retrofit fixture wattage is 77.9, providing a wattage reduction of 37.1 watts per fixture.

Moving on to Table 12-3, we can see how these values would be used in both a pre-retrofit analysis and post-retrofit M&V report. This table is from an actual lighting retrofit project in a northern California community college. In fact, the data is taken directly from the performance contractor's actual spreadsheets which were developed as part of their proposal to the owner. While the performance contractor's presentation of this material was spread over many pages, we were able to obtain copies of the actual spreadsheets and integrate them into a single page which shows the complete picture of the lighting retrofit program proposed for this college campus.

If you look at the table you will note that the lighting fixtures are assembled into three groups based upon their relative operating hours. As can be seen, the Group 1 fixtures operate for a relatively long time each year, generally well in excess of 2,000 hours per year. The second group, by contrast, generally operates between 1,000 and 2,000 hours per year, and the third group operates less than 1,000 hours per year. While the performance contractor in this case definitely was interested in sell-

Table 12-2. 2002 Standard Performance Contract Program
Appendix B-Table of Standard Fixture Wattages

SORTED by Fixture Code	Lamp Code	DESCRIPTION	Ballast	Lamp/ Ballast	Nom. W/Lam	KW/ Fixt
<i>Compact Fluorescent Fixtures</i>						
CF10/2D	CFD10W	Compact Fluorescent, 2D, (1) 10W lamp	Mag-STD	1	10	0.016
CF16/2D	CFD16W	Compact Fluorescent, 2D, (1) 16W lamp	Mag-STD	1	16	0.026
CF21/2D	CFD21W	Compact Fluorescent, 2D, (1) 21W lamp	Mag-STD	1	21	0.026
CF28/2D	CFD28W	Compact Fluorescent, 2D, (1) 28W lamp	Mag-STD	1	28	0.035
CF38/2D	CFD38W	Compact Fluorescent, 2D, (1) 38W lamp	Mag-STD	1	38	0.046
CFQ10/1	CFQ10W	Compact Fluorescent, quad, (1) 10W lamp	Mag-STD	1	10	0.015
CFQ13/1	CFQ13W	Compact Fluorescent, quad, (1) 13W lamp	Mag-STD	1	13	0.017
CFQ13/1-L	CFQ13W	Compact Fluorescent, quad, (1) 13W lamp, BF=1.05	Electronic	1	13	0.015
CFQ13/2	CFQ13W	Compact Fluorescent, quad, (2) 13W lamp	Mag-STD	2	13	0.031
CFQ13/2-L	CFQ13W	Compact Fluorescent, quad, (2) 13W lamp, BF=1.0	Electronic	2	13	0.028
CFQ13/3	CFQ13W	Compact Fluorescent, quad, (3) 13W lamp	Mag-STD	3	13	0.048
CFQ15/1	CFQ15W	Compact Fluorescent, quad, (1) 15W lamp	Mag-STD	1	15	0.020
CFQ17/1	CFQ17W	Compact Fluorescent, quad, (1) 17W lamp	Mag-STD	1	17	0.024
CFQ17/2	CFQ17W	Compact Fluorescent, quad, (2) 17W lamp	Mag-STD	2	17	0.048
CFQ18/1	CFQ18W	Compact Fluorescent, quad, (1) 18W lamp	Mag-STD	1	18	0.026
CFQ18/1-L	CFQ18W	Compact Fluorescent, quad, (1) 18W lamp, BF=1.0	Electronic	1	18	0.020
CFQ18/2	CFQ18W	Compact Fluorescent, quad, (2) 18W lamp	Mag-STD	2	18	0.045
CFQ18/2-L	CFQ18W	Compact Fluorescent, quad, (2) 18W lamp, BF=1.0	Electronic	2	18	0.038
CFQ18/4	CFQ18W	Compact Fluorescent, quad, (4) 18W lamp	Mag-STD	2	18	0.090
CFQ20/1	CFQ20W	Compact Fluorescent, quad, (1) 20W lamp	Mag-STD	1	20	0.023
CFQ20/2	CFQ20W	Compact Fluorescent, quad, (2) 20W lamp	Mag-STD	2	20	0.046
CFQ22/1	CFQ22W	Compact Fluorescent, Quad, (1) 22W lamp	Mag-STD	1	22	0.024
CFQ22/2	CFQ22W	Compact Fluorescent, Quad, (2) 22W lamp	Mag-STD	2	22	0.048
CFQ22/3	CFQ22W	Compact Fluorescent, Quad, (3) 22W lamp	Mag-STD	3	22	0.072
CFQ25/1	CFQ25W	Compact Fluorescent, Quad, (1) 25W lamp	Mag-STD	1	25	0.033
CFQ25/2	CFQ25W	Compact Fluorescent, Quad, (2) 25W lamp	Mag-STD	2	25	0.066

CFQ26/1	CFQ26W	Compact Fluorescent, quad, (1) 26W lamp	Mag-STD	1	26	0.033
CFQ26/1-L	CFQ26W	Compact Fluorescent, quad, (1) 26W lamp, BF=0.95	Electronic	1	26	0.027
CFQ26/2	CFQ26W	Compact Fluorescent, quad, (2) 26W lamp	Mag-STD	2	26	0.066
CFQ26/2-L	CFQ26W	Compact Fluorescent, quad, (2) 26W lamp, BF=0.95	Electronic	2	26	0.050
CFQ26/3	CFQ26W	Compact Fluorescent, quad, (3) 26W lamp	Mag-STD	3	26	0.099
CFQ26/6-L	CFQ26W	Compact Fluorescent, quad, (6) 26W lamp, BF=0.95	Electronic	6	26	0.150
CFQ28/1	CFQ28W	Compact Fluorescent, quad, (1) 28W lamp	Mag-STD	1	28	0.033
CFQ9/1	CFQ9W	Compact Fluorescent, Quad, (1) 9W lamp	Mag-STD	1	9	0.014
CFQ9/2	CFQ9W	Compact Fluorescent, Quad, (2) 9W lamp	Mag-STD	2	9	0.023
CFT13/1	CFT13W	Compact Fluorescent, twin, (1) 13W lamp	Mag-STD	1	13	0.017
CFT13/2	CFT13W	Compact Fluorescent, twin, (2) 13W lamp	Mag-STD	2	13	0.031
CFT13/3	CFT13W	Compact Fluorescent, twin, (3) 13W lamp	Mag-STD	3	13	0.048
CFT18/1	CFT18W	Compact Fluorescent, Long twin., (1) 18W lamp	Mag-STD	1	18	0.024
CFT22/1	CFT22W	Compact Fluorescent, twin, (1) 22W lamp	Mag-STD	1	22	0.027
CFT22/2	CFT22W	Compact Fluorescent, twin, (2) 22W lamp	Mag-STD	2	22	0.054
CFT22/4	CFT22W	Compact Fluorescent, twin, (4) 22W lamp	Mag-STD	4	22	0.108
CFT24/1	CFT24W	Compact Fluorescent, long twin., (1) 24W lamp	Mag-STD	1	24	0.032
CFT28/1	CFT28W	Compact Fluorescent, twin, (1) 28W lamp	Mag-STD	1	28	0.033
CFT28/2	CFT28W	Compact Fluorescent, twin, (2) 28W lamp	Mag-STD	2	28	0.066
CFT32/1-L	CFM32W	Compact Fluorescent, twin or multi, (1) 32W lamp	Electronic	1	32	0.034
CFT32/2-L	CFM32W	Compact Fluorescent, twin or multi, (2) 32W lamp	Electronic	2	32	0.062
CFT32/6-L	CFM32W	Compact Fluorescent, twin or multi, (2) 32W lamp	Electronic	6	32	0.186
CFT36/1	CFT36W	Compact Fluorescent, long twin., (1) 36W lamp	Mag-STD	1	36	0.051
CF40/1	CFT40W	Compact Fluorescent, twin, (1) 40W lamp	Mag-STD	1	40	0.046
CFT40/1-L	CFT40W	Compact Fluorescent, long twin., (1) 40W lamp	Electronic	1	40	0.043
CFT40/2	CFT40W	Compact Fluorescent, twin, (2) 40W lamp	Mag-STD	2	40	0.085
CFT40/2-L	CFT40W	Compact Fluorescent, long twin., (2) 40W lamp	Electronic	2	40	0.072
CFT40/3	CFT40W	Compact Fluorescent, twin, (3) 40W lamp	Mag-STD	3	40	0.133
CFT40/3-L	CFT40W	Compact Fluorescent, long twin., (3) 40W lamp	Electronic	3	40	0.105
CFT5/1	CFT5W	Compact Fluorescent, twin, (1) 5W lamp	Mag-STD	1	5	0.009
CFT5/2	CFT5W	Compact Fluorescent, twin, (2) 5W lamp	Mag STD	2	5	0.018

Table 12-3. Lighting Fixture Retrofit Analysis
Solano Community College

GROUP 1 FIXTURES						Fixture Size
Fix. Code	Existing System	Retrofit System	Retro. Qty	Installed Cost	Extension	
A	1-20w T12 lamp, Mag. Bal.	1-17w T8 lamp, Low Pwr. Bal.	20	\$ 43.30	\$ 866.00	2'
-B-	1-100w Incand lamp	1-45w Halo PAR,	154	\$ 20.00	\$ 3,080.00	Downlight
-C-	8-34w T12 lamp, Mag. Bal.	4-32w T8 lamp, Low Pwr. Bal., SBR Refl.	28	\$ 139.37	\$ 3,902.36	4 x 4
-D-	2-160w T12 lamp (VHO), Mag. Bal.	4-25w T8 lamp, Elec. Bal.	74	\$ 119.35	\$ 8,831.90	6'
-E-	1-110w T12 lamp (HO), Mag. Bal.	2-32w T8 lamp, Elec. Bal.	75	\$ 100.10	\$ 7,507.50	8'
-F-	2-110w T12 lamp (HO), Mag. Bal.	4-32w T8 lamp, Elec. Bal.	207	\$ 116.03	\$ 24,018.21	8'
-G-	1-160w T12 lamp (VHO), Mag. Bal.	2-32w T8 lamp, Elec. Bal.	53	\$ 97.12	\$ 5,147.36	6'
-B-	1-100w Incand lamp	1-45w Halo PAR,	102	\$ 128.29	\$ 15,683.88	Downlight
-C-	8-34w T12 lamp, Mag. Bal.	4-32w T8 lamp, Low Pwr. Bal., SBR Refl.	103	\$ 136.76	\$ 17,665.60	5 x 4
J	2-250w Mercury Vapor Lamps	New HPS 2-150w Fixtures	30	\$ 522.36	\$ 15,670.80	Downlight
-K-	1-400w Mercury Vapor Lamp	New HPS 1-200w Fixture	44	\$ 308.88	\$ 13,590.72	Downlight
-L-	4-400w Mercury Vapor Lamps	New HPS 4-200w Fixtures	9	\$ 1,191.07	\$ 10,719.63	Downlight
N	1-100w Mercury Vapor Lamp	New HPS 1-70w Fixture	43	\$ 190.78	\$ 8,203.54	Downlight
O	2-200w Mercury Vapor Lamps	New HPS 2-70w Fixtures	27	\$ 348.24	\$ 9,402.48	Downlight
Q	2-15w Incand, exits	New Dual Lite LED Exit Fixture	95	\$ 92.32	\$ 8,770.40	ew LED 2S
Lamp Disposal						\$ 484.32
Totals						\$130,600

GROUP 2 FIXTURES						Fixture Size
Fix. Code	Existing System	Retrofit System	Retro. Qty	Installed Cost	Extension	
A	1-200w Incand. lamp	1-150w Halo PAR,	72	\$ 21.22	\$ 1,527.84	Downlight
B	1-34w T12 lamp, Mag. Bal.	1-32w T8 lamp, Low Pwr. Bal.	109	\$ 42.31	\$ 4,611.79	1 x 4
C	2-34w T12 lamp, Mag. Bal.	2-32w T8 lamp, Low Pwr. Bal., SBR Refl.	2,283	\$ 67.51	\$ 154,125.33	1 x 4
D	3-34w T12 lamp, Mag. Bal.	2-32w T8 lamp, Elec. Bal., SBR Refl.	260	\$ 82.69	\$ 21,499.40	2 x 4
-D1-	4-34w T12 lamp, Mag. Bal.	2-32w T8 lamp, Elec. Bal., SBR Refl.	572	\$ 82.69	\$ 47,298.68	2 x 4
-E-	6-34w T12 lamp, Mag. Bal.	4-32w T8 lamp, Low Pwr. Bal., SBR Refl.	4	\$ 139.37	\$ 557.48	4 x 4
F	1-55w T12 lamp, Mag. Bal.	2-25w T8 lamp, Elec. Bal.	26	\$ 100.26	\$ 2,606.76	6'
-G-	3-75w T12 lamp, Mag. Bal.	4-32w T8 lamp, Elec. Bal., SBR Refl.	243	\$ 136.90	\$ 33,266.70	2 x 8
K	3-100w PAR Incand.	3-90w Halo PAR,	53	\$ 53.27	\$ 2,823.31	Downlight
L	2-400w Mercury Vapor Lamps	New HPS 2-200w Fixtures	24	\$ 601.09	\$ 14,426.16	Downlight
Lamp Disposal						\$ 2,964.48
Totals						\$285,708

GROUP 3 (LESS THAN 1000 HOUR BURN)						Fixture Size
Fix. Code	Existing System	Retrofit System	Retro. Qty	Installed Cost	Extension	
A	2-34w T12 lamp, Mag. Bal.	2-32w T8 lamp, Low Pwr. Bal.	519	\$ 45.80	\$ 23,770.20	1 x 4
B	3-34w T12 lamp, Mag. Bal.	2-32w T8 lamp, Elec. Bal., SBR Refl.	49	\$ 82.69	\$ 4,051.81	2 x 4
C	4-34w T12 lamp, Mag. Bal.	2-32w T8 lamp, Elec. Bal., SBR Refl.	279	\$ 82.69	\$ 23,070.51	2 x 4
-D-	2-100w Incand. lamp	1-45w Halo Lamp	176	\$ 20.00	\$ 3,520.00	Downlight
E	3-75w Incand lamp	3-45w Halo Lamp	5	\$ 52.09	\$ 260.45	Downlight
F	2-110w T12 lamp, Mag. Bal.	4-32w T8 lamp, Elec. Bal.	26	\$ 116.03	\$ 3,016.78	8'
G	2-75w T12 lamp, Mag. Bal.	4-32w T8 lamp, Elec. Bal.	47	\$ 68.80	\$ 3,233.60	8'
H	MV 1-1000w	HPS 1-400w	10	\$ 308.88	\$ 3,088.80	Downlight
I	MV 1-1500w	MH 1-1500w	96	\$ 879.34	\$ 85,216.64	Downlight
J	1-300w Incand lamp	MH 1-175w	161	\$ 279.35	\$ 44,975.35	Downlight
Lamp Disposal						\$ 829.76
Totals						\$175,034

ALL THREE GROUPS COMBINED:	6,301	\$591,342
GROUPS 1 AND 2 COMBINED:	4,933	\$416,308
OPTIMIZED SELECTION (Codes marked "-A-"):	4,517	\$339,718

ing as much lighting retrofit as possible, we had to applaud the fact that they laid all the information out on the table for the owner to peruse and consider. In fact, we employed their data in a fashion that allowed the owner the "cherry pick" the best return on investment if they chose to do

10/28/02

Fixture Quantity		Ballast Quantity		Lamp Quantity		Input Watts		Burn Hours	Kwh Cost	Current Kwh/yr	Retrofit Kwh/yr	Kwh/yr Saved	Cost Saved	
Pre	Post	Pre	Post	Pre	Post	Pre	Post							
20	20	0.5	1	1	1	20	18	3,492	0.118	1397	1257	140	\$16	
154	154	0	0	1	1	100	45	2,321	0.118	35743	18085	19859	\$2,320	
28	28	4	1	8	4	312	95	2,250	0.118	19656	5985	13671	\$1,613	
74	74	1	1	2	4	335	84	2,250	0.118	55778	13986	41792	\$4,931	
75	75	1	1	1	2	230	58	2,285	0.118	39416	9940	29477	\$3,478	
207	207	1	1	2	4	450	105	2,454	0.118	228590	53846	174744	\$20,620	
53	53	1	1	1	2	175	58	2,213	0.118	20526	6803	13723	\$1,619	
102	102	0.9	1.3	0.6	1.3	335	82	2,306	0.118	78742	19142	59601	\$7,033	
103	103	0.8	1.5	0.1	3.22	355	84	2,309	0.118	84214	19833	64381	\$7,597	
30	30	0	0	2	2	450	300	3,267	0.118	44105	29403	14702	\$1,735	
44	44	0	0	1	1	400	200	2,389	0.118	42046	21023	21023	\$2,481	
9	9	0	0	4	4	1800	800	3,650	0.118	59130	25280	32850	\$3,876	
43	43	0	0	1	1	100	70	2,217	0.118	9533	6673	2860	\$337	
27	27	0	0	2	2	236	140	2,887	0.118	18396	10913	7483	\$883	
95	95	0	0	2	1	30	2	8,760	0.075	24966	1664	23302	\$1,748	
Totals		KW= 300		94		KW RED= 206		762237		242832		519406		\$60,288

Fixture Quantity		Ballast Quantity		Lamp Quantity		Input Watts		Burn Hours	Kwh Cost	Current Kwh/yr	Retrofit Kwh/yr	Kwh/yr Saved	Cost Saved	
Pre	Post	Pre	Post	Pre	Post	Pre	Post							
72	72	0	0	1	1	200	150	1,330	0.088	19152	14364	4788	\$421	
109	109	1	1	1	1	50	30	1,350	0.088	7358	4415	2943	\$259	
2,283	2,283	1	1	2	2	78	51	1,858	0.088	330861	216333	114529	\$10,079	
260	260	1.5	1	3	2	120	58	1,674	0.088	52229	25244	26985	\$2,375	
572	572	2	1	4	2	156	58	1,914	0.088	107090	63499	107291	\$9,442	
4	4	3	1	6	4	234	95	1,680	0.088	1572	638	934	\$82	
26	26	1	1	1	2	68	42	1,222	0.088	2160	1334	826	\$73	
243	243	2	1	3	4	270	106	1,100	0.088	72171	28334	43837	\$3,858	
53	53	0	0	3	3	300	270	1,541	0.088	24502	22052	2450	\$216	
24	24	0	0	2	2	900	400	1,564	0.088	33782	15014	18768	\$1,652	
Totals		KW= 424		230		KW RED= 194		714578		391227		323352		\$28,455

Fixture Quantity		Ballast Quantity		Lamp Quantity		Input Watts		Burn Hours	Kwh Cost	Current Kwh/yr	Retrofit Kwh/yr	Kwh/yr Saved	Cost Saved	
Pre	Post	Pre	Post	Pre	Post	Pre	Post							
519	519	1	1	2	2	96	51	336	0.088	16741	8894	7847	\$691	
49	49	2	1	3	2	140	58	803	0.088	5509	2282	3226	\$284	
279	279	2	1	4	2	192	58	398	0.088	21320	6440	14880	\$1,309	
176	176	0	0	2	1	200	45	518	0.088	18234	4103	14131	\$1,244	
5	5	0	0	3	3	225	135	100	0.088	113	68	45	\$4	
26	26	1	1	2	4	450	105	565	0.088	6611	1557	5053	\$445	
47	47	1	1	2	4	175	105	739	0.088	6078	3682	2397	\$211	
10	10	0	0	1	1	1075	400	365	0.088	3924	1460	2464	\$217	
96	96	0	0	1	1	1600	1500	12	0.088	1843	1728	115	\$10	
161	161	0	0	1	1	300	175	558	0.088	26951	15722	11230	\$988	
Totals		KW= 379		238		KW RED= 141		107323		45935		61388		\$5,402

KW= 1104	562	KW RED= 541	1584138	679993	904145	\$94,145
KW= 725	324	KW RED= 400	1476816	634058	842757	\$88,743
KW= 659	273	KW RED= 387	1301588	521856	779732	\$82,441

so. This was facilitated by the fact that the performance contractor provided their actual proposed sell price per fixture to the client as a part of the spreadsheet, which is identified as installed cost. This is not an engineer's estimated cost, but rather, the performance contractor's actual sell price per fixture being offered to the owner. Obviously, if the owner "cherry picked" the work such that the total volume of fixtures retrofit-

ted were but a very small fraction of the total number of fixtures on the campus, then the performance contractor might not be willing to honor these proposed prices. Again, we applaud the performance contractor for putting this kind of information on the table so as to assist the owner to make a rational decision.

Looking at the table we can see that it provides a description of the existing fixture, how it is to be retrofitted, the quantity of fixtures to be retrofitted, the unit installation cost, and the extended total cost for that quantity of fixtures. In addition, information like the size and type of fixtures provided, as we move across the table, including both a pre and post-retrofit fixture quantity (in this case the same for every type of fixture, though this would not ordinarily always be the case), the ballast quantity (note that tandem wiring is assumed in certain cases), the pre- and post-retrofit lamp counts, the pre- and post-retrofit fixture watts, and the annual burn hours. Note that the annual burn hours vary significantly for each of the types of fixtures involved. Once again, we applaud this performance contractor, as we frequently see lighting retrofit analysis reports which assume a uniform burn hours value throughout the facility for every type of fixture, and frequently these burn hours are extremely optimistic (that is, in favor of the performance contractor). In fact, one of the case studies discussed in this text that resulted in a failed project was based on an assumed 8760 hours per year, on a one shift-per-day, five days-per-week county office building operation, which was ultimately determined to be totally fallacious.

The final five columns of this table are actually where the results take place. First of all, a kilowatt-hour cost is stated for each type of fixture. These numbers are weighted average unit cost for a kilowatt-hour and their method will be explained a bit further in this chapter. Note that three different weighted average unit costs are employed in the calculations. The table next displays the current or pre-retrofit kilowatt-hours per year of electricity consumed by each of the lighting fixtures. This is the result of multiplying the pre-retrofit input watts per fixture times the number of fixtures times the annual burn hours. The retrofit kilowatt-hours per year are similarly developed only by using the post-retrofit values for the input watts and the quantity of fixtures. Note that the annual burn hours are assumed to remain the same before and after the retrofit is performed. In the next to last column the difference in the pre-retrofit and the post-retrofit kilowatt-hours per year is calculated by simply taking the difference, and in the last column kilowatt-hours per year

saved are multiplied by the kilowatt-hour cost in the table to produce an annual cost avoidance for each fixture, which is stated as "cost saved."

As can be seen, a total cost to retrofit is calculated for each group as well as the annual cost avoidance produced by the retrofit. These are done for each of the groups in the table and then are summarized at the bottom of the table showing all three groups combined and other alternative schemes of retrofit. Note that all of the retrofit work combined provides a total cost of just over \$590,000 with an annual savings a bit over \$90,000 per year, for a payback slightly in excess of six years. By eliminating the third group which has a very low burn hours and relatively low savings compared to the installed cost we take nearly \$200,000 of costs away but reduce the annual savings by less than 10% bringing the payback down to less than five years. Finally, an optimized selection is presented where each of the individual fixture types in each group are "cherry picked" to provide a retrofit package whose installed cost is just over half of the total for doing all of the fixtures yet the annual savings is just under 90% of the for savings retrofitting all fixtures, thereby resulting in a simple payback of just over four years.

WEIGHTED AVERAGE UNIT COST OF ELECTRICITY

It is in some ways a strange curiosity that the "micro-profession" of measurement and verification has generally ignored the financial side of the question. That is, a component which is conspicuously absent from the IPMVP is any treatment of the conversion of units of energy into dollars saved or costs avoided. This situation may very well be the result of the fact that the vast majority of the professionals involved in measurement and verification come from an engineering point of view and prefer to deal with engineering units only. This should probably be considered a significant weakness as it has been our experience that building owners in fact care very little about saving energy, but care very much about saving money.

An addition to the IPMVP has been proposed to the technical committee but, for the reasons stated above was not implemented in the 1997 IPMVP's successor, "IPMVP 2000." This proposed addition is provided as an appendix entitled "Valuing Energy Savings," which discusses many different ways of establishing the value of a kilowatt-hour saved. This appendix is commended to the reader's consideration, however, we

will discuss the particular method of establishing a weighted average unit cost as follows below.

Tables 12-4, 12-5 and 12-6 all employ the identical spreadsheet and are three examples demonstrating how a weighted average unit cost can be established with a high degree of confidence, so that the two parties to a contract can feel comfortable in stipulating such a value.

Looking at Table 12-4, we can see that this spreadsheet is divided into four basic components. First of all, in the upper third of the spreadsheet we have calculations for the summer season. Immediately below it we have calculations for the winter season. In the bottom third of the spreadsheet we see details of the average weight schedule being employed and to the right of that, a summary of the results of the analysis.

Looking at the summer calculations we can see that each time of use period is defined in this portion of the spreadsheet. For this particular rate schedule, there are peak (as most would refer to it, on-peak), part-peak and off-peak periods. Notice that both the Monday-through-Friday and Saturday/Sunday/Holiday periods are covered. As can be seen, the starting and ending time of each of these time of use periods is shown. Adjacent to this, the available hours per day in each of these time periods is calculated. Next to this, the occupied hours per day are shown for the particular type of operation for which the spreadsheet is being used. Note that for Table 12-4 these numbers are all the same because we are describing a 24-hour-per-day operation. By contrast, in Table 12-5 the occupied hours per day are much less than the available hours per day in many time of use periods, because we are describing a typical 12-hour-per-day office space. Similarly, in Table 12-6 where we are describing night time lighting, the occupied hours per day are again significantly different in many cases.

In the next column we describe the percent of the load or facility which is in use. In fact, we could avoid this column entirely by simply adjusting the occupied hours per day, but including it makes the analysis more easily understandable to bystanders (which is a critical part of performing measurement and verification).

In the next column we calculate the hours of use per day which is the product of the occupied hours per day times the percent in use. The table next displays the days per week and the weeks per season in order to calculate the days per season. The next column, hours of use, is calculated by multiplying the hours of use per day by the days per season. We can then take the kilowatt-hour unit cost directly from the actual rate

Table 12-4. Average Electrical Cost Analysis (based on time of use/savings)

NOTES: * WEEKDAYS "DAYS PER SEASON" ARE LESS HOLIDAYS
** DEMAND COST SEASON SUB-TOTALS ARE FOR 6 MONTHS

WEEKDAYS DAY AFTER SEASON ARE EXECUTIVE DAYS
DEMAND SOFT SEASON SUB TOTALS ARE FOR 6 MONTHS

1. ALL SIMULATIONS ASSUME A 10% CAP.

1. ALL CALCULATIONS ASSUME A 1 KW LOAD
2. 100% EMISSIONS REDUCTION IN EMISSIONS RATE IN EFFECT FOR REGION

2. ALL DEMAND COSTS ARE "% IN USE" TIMES RATE IN EFFECT FOR PERIOD

RESULTS OF ANALYSIS

TOTAL DEMAND (KW) COST: \$155

TOTAL ENERGY (KWH) COST: \$500

TOTAL COST: \$654

TOTAL COST/KWH: \$0.075

AVERAGE COST/KWH W/O DEMAND: \$0.057

Table 12-5. Average Electrical Cost Analysis (based on time of use/savings)

TIME OF USE (TOU) GROUP:		2 TYPICAL OFFICE USAGE FROM 7 A.M. TO 7 P.M.												DATE: 10/28/02							
DESCRIPTION:														INIT: HK							
CALCULATIONS:		HRS OF USE																			
SEASON:	SUMMER	AVAIL.	OCC.	HRS OF USE																	
(TOU)	---TIME---	HRS	HRS.	%	USE	PER	PER	IN	PER	PER	PER	PER	HRS	KWH	TOTAL	**PEAK	**PART	**MAX			
PERIOD		PER	PER		DAY	DAY	DAY	USE	DAY	WEEK	SEASON	SEASON	USE	OF UNIT	ENERGY COST	DEM COST	DEM COST	DEM COST			
OFF-PEAK	M/F	2400	830	8.5	1.5	x	100%	=	1.5	5	26.2	128	192.0	\$0.05059	\$9.71	\$0	\$0.00	\$2.55			
PART-PEAK	M/F	830	1200	3.5	3.5	x	100%	=	3.5	5	26.2	128	448.0	\$0.05810	\$26.03	\$0	\$3.70	\$0.00			
PEAK	M/F	1200	1800	6	6.0	x	100%	=	6.0	5	26.2	128	768.0	\$0.08773	\$67.38	\$13.35	\$0.00	\$0.00			
PART-PEAK	M/F	1800	2130	3.5	1.0	x	100%	=	1.0	5	26.2	128	128.0	\$0.05810	\$7.44	\$0	\$0.00	\$0.00			
OFF-PEAK	M/F	2130	2400	2.5	0.0	x	100%	=	0.0	5	26.2	128	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00			
OFF-PEAK	S/S	0000	2400	24	0.0	x	100%	=	0	2	26.0	52	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00			
OFF-PEAK	H	0000	2400	24	0.0	x	100%	=	0	N/A	N/A	3	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00			
SUMMER SEASON TOTALS												183	1536	\$110.56	\$80.10	\$22.20	\$15.30				
SEASON:	WINTER	AVAIL.	OCC.	HRS OF USE																	
(TOU)	---TIME---	HRS	HRS.	%	USE	PER	PER	IN	PER	PER	PER	PER	HRS	KWH	TOTAL	**PEAK	**PART	**MAX			
PERIOD		PER	PER		DAY	DAY	DAY	USE	DAY	WEEK	SEASON	SEASON	USE	OF UNIT	ENERGY COST	DEM COST	DEM COST	DEM COST			
OFF-PEAK	M/F	2400	830	8.5	1.5	x	100%	=	1.5	5	26.0	125	187.5	\$0.05038	\$9.45	\$0	\$0.00	\$2.55			
PART-PEAK	M/F	830	1200	3.5	3.5	x	100%	=	3.5	5	26.0	125	437.5	\$0.06392	\$27.97	\$0	\$3.65	\$0.00			
PART-PEAK	M/F	1200	1800	6	6.0	x	100%	=	6.0	5	26.0	125	750.0	\$0.06392	\$47.94	\$0	\$0.00	\$0.00			
PART-PEAK	M/F	1800	2130	3.5	1.0	x	100%	=	1.0	5	26.0	125	125.0	\$0.06392	\$7.99	\$0	\$0.00	\$0.00			
OFF-PEAK	M/F	2130	2400	2.5	0.0	x	100%	=	0.0	5	26.0	125	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00			
OFF-PEAK	S/S	0000	2400	24	0.0	x	100%	=	0	2	26.0	52	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00			
OFF-PEAK	H	0000	2400	24	0.0	x	100%	=	0	N/A	N/A	5	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00			
WINTER SEASON TOTALS												182	1500	\$93.34	\$0.00	\$21.90	\$15.30				
ANNUAL TOTALS:												365	3036	\$203.90	\$80.10	\$44.10	\$30.80				
ACTUAL RATE SCHEDULE:												RESULTS OF ANALYSIS									
RATE:	PG&E E19S	EFFECTIVE:	1/1/98																		
DEMAND CHARGES (per KW)		SUMMER		WINTER																	
MAX. PEAK:		\$13.35		\$0.00												\$155					
MAX PART-PEAK:		\$3.70		\$3.65												\$204					
MAX DEMAND:		\$2.55		\$2.55																	
ENERGY CHARGES (per KWh)																					
PEAK:		\$0.08773		\$0.00												\$0.118					
PARTIAL-PEAK:		\$0.05810		\$0.06392																	
OFF-PEAK:		\$0.05059		\$0.05038												\$0.067					

NOTES: * WEEKDAYS "DAYS PER SEASON" ARE LESS HOLIDAYS

** DEMAND COST SEASON SUB-TOTALS ARE FOR 6 MONTHS

1. ALL CALCULATIONS ASSUME A 1 KW LOAD

2. ALL DEMAND COSTS ARE "% IN USE" TIMES RATE IN EFFECT FOR PERIOD

3. COST CALCULATED HEREIN MAY BE USED FOR VALUING CONSUMPTION OR SAVINGS

Table 12-6. Average Electrical Cost Analysis (based on time of use/savings)

TIME OF USE (TOU) GROUP:			3												DATE: 10/28/02					
DESCRIPTION: NIGHT LIGHTING FROM 8 PM TO 1 AM															INIT. HK					
CALCULATIONS:																				
SEASON:	SUMMER	AVAIL.	OCC.	HRS																
(TOU)	---TIME---	HRS	HRS.	%	USE	OF	DAYS	WEEKS	*DAYS	HRS	KWH	TOTAL	**PEAK	**PART	**MAX	DEM	DEM			
PERIOD		DAY	DAY	IN	PER	PER	PER	PER	PER	USE	OF	ENERGY	DEM	DEM	DEM	DEM	DEM			
OFF PEAK	M/F	2400	830	8.5	1.0	x	100%	=	1.0	5	26.2	128.0	\$0.05059	\$6.48	\$0	\$0.00	\$0.00			
PART-PEAK	M/F	830	1200	3.5	0.0	x	0%	=	0.0	5	26.2	0.0	\$0.05810	\$0.00	\$0	\$0.00	\$0.00			
PEAK	M/F	1200	1800	6	0.0	x	0%	=	0.0	5	26.2	0.0	\$0.08773	\$0.00	\$0.00	\$0.00	\$0.00			
PART-PEAK	M/F	1800	2130	3.5	1.5	x	100%	=	1.5	5	26.2	192.0	\$0.05810	\$11.16	\$0	\$3.70	\$0.00			
OFF-PEAK	M/F	2130	2400	2.5	2.5	x	100%	=	2.5	5	26.2	320.0	\$0.05059	\$16.19	\$0	\$0.00	\$0.00			
OFF-PEAK	S/S	0000	2400	24	0.0	x	0%	=	0	2	26.0	52	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00		
OFF-PEAK	H	0000	2400	24	0.0	x	0%	=	0	N/A	N/A	3	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00		
SUMMER SEASON TOTALS:															\$33.82	\$0.00	\$22.20	\$0.00		
SEASON:	WINTER	AVAIL.	OCC.	HRS																
T	(TOU)	---TIME---	HRS	HRS.	%	USE	OF	DAYS	WEEKS	*DAYS	HRS	KWH	TOTAL	**PEAK	**PART	**MAX	DEM	DEM		
PERIOD		DAY	DAY	IN	PER	PER	PER	PER	PER	PER	USE	OF	ENERGY	DEM	DEM	DEM	DEM	DEM		
OFF-PEAK	M/F	2400	830	8.5	1.0	x	100%	=	1.0	5	26.0	125.0	\$0.05038	\$6.30	\$0	\$0.00	\$0.00			
PART-PEAK	M/F	830	1200	3.5	0.0	x	0%	=	0.0	5	26.0	0.0	\$0.05392	\$0.00	\$0	\$0.00	\$0.00			
PART-PEAK	M/F	1200	1800	6	0.0	x	0%	=	0.0	5	26.0	0.0	\$0.05392	\$0.00	\$0	\$0.00	\$0.00			
PART-PEAK	M/F	1800	2130	3.5	1.5	x	100%	=	1.5	5	26.0	187.5	\$0.05392	\$11.99	\$0	\$3.65	\$0.00			
OFF-PEAK	M/F	2130	2400	2.5	2.5	x	100%	=	2.5	5	26.0	312.5	\$0.05038	\$15.74	\$0	\$0.00	\$0.00			
OFF-PEAK	S/S	0000	2400	24	0.0	x	0%	=	0	2	26.0	52	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00		
OFF-PEAK	H	0000	2400	24	0.0	x	0%	=	0	N/A	N/A	5	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00		
WINTER SEASON TOTALS:															\$34.03	\$0.00	\$21.90	\$0.00		
ANNUAL TOTALS:															365	1265	\$67.85	\$0.00	\$44.10	\$0.00
ACTUAL RATE SCHEDULE															RESULTS OF ANALYSIS					
RATE:	PG&E E19S	EFFECTIVE:	1/1/98																	
DEMAND CHARGES (per kW)	SUMMER		WINTER																	
MAX PEAK:	\$13.35		\$0.00																	
MAX PART-PEAK:	\$3.70		\$3.65																	
MAX DEMAND:	\$2.55		\$2.55																	
ENERGY CHARGES (per kWh)																				
PEAK:	\$0.08773		\$0.00																	
PARTIAL-PEAK:	\$0.05810		\$0.06392																	
OFF-PEAK:	\$0.05059		\$0.05038																	

NOTES: * WEEKDAYS "DAYS PER SEASON" ARE LESS HOLIDAYS

** DEMAND COST SEASON SUB-TOTALS ARE FOR 6 MONTHS

1. ALL CALCULATIONS ASSUME A 1 KW LOAD

2. ALL DEMAND COSTS ARE "% IN USE" TIMES RATE IN EFFECT FOR PERIOD

3. COST CALCULATED HEREIN MAY BE USED FOR VALUING CONSUMPTION OR SAVINGS

schedule which has been entered into the spreadsheet, and, assuming a 1 kW load as stated in the notes, we can calculate a total energy cost for each time of use period in the season.

In the next three columns the demand costs are calculated. Note that only one value is shown in each column which is the peak value during each of the time of use periods. Also note that in Table 12-6 there is no maximum demand cost shown, because the spreadsheet has been constrained to look only at the daytime energy use for loads which would likely contribute to the building's overall maximum demand, and therefore it only looks at the 8:30 a.m. to 6:00 p.m. timeframe for maximum demand charges. It should further be noted that this is one of the small weaknesses of calculating a weighted average unit cost, in that demand charges are attributable to a specific individual load only if that load combines with the other loads in the building to cause or increase the high demand value during a time of use period. The same issue will be dealt with under some of the Option B methods as well, as we will see later.

Returning to Table 12-4, we can see that the days per season, hours of use, total energy cost and demand cost are all totaled for the season. As shown in the footnotes, the demand charges are the product of six months multiplied by the value shown in the column. Similar calculations are done for the winter season, noting that there are only two time of use periods in existence in the winter season under this rate schedule. Finally, annual totals are created for the values calculated for each of the seasons. These are notable, and somewhat important in the sense of error checking, in that the annual totals need to make sense. Note that the annual days per season totals to 365 days, which is the correct number of days in year. A number other than 365 would indicate that some error has been made in editing the spreadsheet. This is always a potential problem in allowing untutored users to "muck about" with an unprotected spreadsheet. Also note that the annual hours of use for a 24-hour-a-day operation equal the total number hours in a year, i.e. 8760 hours. Since we are assuming a 1 kW load, the annual hours of use are also equal to the annual kilowatt-hours.

In the results of the analysis all of the demand charges are totaled and all of the energy charges are totaled, providing a total cost which can then be divided by the annual hours of use (or annual kWh). Since demand charges can be a dramatic and important part of the value of the cost of energy, an average cost per kilowatt-hour (without demand charges) is also shown for comparison. Note that the total cost per kilo-

watt-hour in Table 12-5 is 11.8 cents due to the high concentration of daytime energy use in an office area which occurs during a high-cost time of use period. Note that in Table 12-6 the average unit cost is 8.8 cents per kilowatt-hour primarily because the hours of use are concentrated mainly in the part-peak and somewhat in the off-peak period, whereas the average unit cost calculated in Table 12-4 is the lowest of the three because so very many of the hours of use occur at night and on the weekends, when the time of use charges are the very lowest.

As a final note, this methodology is applicable to calculate both the cost of using a kilowatt-hour and the value of a kilowatt-hour that is not used. That is, if you are simply reducing a load, you can calculate what it costs to operate the load, and if you reduce that load by 50%, then the same unit costs apply to the energy used as to the energy not used. By contrast, if you want to calculate the value of a kilowatt-hour that is not used at all, i.e., from turning a load off rather than just reducing its magnitude, then the spreadsheet should be used to describe the hours of use of the load which will no longer be used because it will be turned off by an automatic control system. This concept is perhaps a bit subtle and perhaps not at all obvious at first blush, but it is powerful upon reflection.

OPTION A VARIABLE AIR VOLUME RETROFIT

For this retrofit measure we will use method VSD-A01, spot metering. In order to implement this methodology we perform the following steps:

1. We will actually field measure the existing motor load and/or load profile.
2. We will measure (or stipulate) the retrofit system at various loads (we will monitor over short period of time and develop a linear regression or other algorithm which relates outside air temperature to cooling load and then to fan power).
3. We will apply the retrofit algorithm to the annual load profile.
4. We will calculate units of energy saved by subtracting the post-retrofit energy use from the baseline energy use.

5. We will calculate the cost savings or avoided cost by multiplying the units of energy saved times a unit cost.
6. Cooling and heating savings will be stipulated from the fan power savings calculation, and which will likely be adjusted according to the actual fan power savings, i.e., if the motor savings are down by 10%, the heating and cooling savings would also be adjusted downward by 10%.

Looking at Table 12-7 we see an array which includes a typical daily temperature and load profile for a typical day for each month of the year. Since we are anticipating that the variable air volume system will allow the system airflow to follow the total cooling load as opposed to operating at constant volume regardless of load, the establishment of a mutually agreeable annual load profile is a necessity in this case. This load profile can be computer-generated by using a building simulation program, or, as was done in this particular case, can be the result of monitoring cooling plant load versus outside air temperature for a relatively short period of time and then rationally extrapolating this small amount of data to an entire year's load profile. The process by which this particular load profile was developed is discussed in some detail in the appendix entitled "Technical Bulletin Estimating Chiller Load from Percent Full Load Amps."

Moving on to Table 12-8, we see a cost avoidance report for an entire month. Note, that for this option, Option A, there will be a single page report for each day type for the entire month of June for the VAV cost avoidance. Typically the number of day-types that will be defined in an M&V plan will be as little as three, for example, "Weekday," "Saturday" and "Sunday/Holiday" day-types. As we will see later, this is relatively simplistic compared to the volume of reports which will be generated by using Option B when we do continuous measurement in the post-retrofit period.

Note that this report shown in Table 12-8 is for a weekday day type. In this particular case we are assuming that the peak demand of the air handling system's fan motor will contribute directly and 100% to the building's peak demand since the building will probably peak at about the time the air conditioning peaks as well. For this reason the peak demand factor for this table is entered as 1.0. Also note that the peak annual load in tons is listed as we need to know this to gauge what

Table 12-7.

TITLE: XICOR/TES_SDY	SYS	WEEKDAY COOLING LOAD PROFILES AND HOURLY TEMPERATURES																								Avg Load	TON-HRS PER MO.
		ON? 0/1	1 0	2 1	3 2	4 3	5 4	6 5	7 6	8 7	9 8	10 9	11 10	12 11	13 12	14 1	15 2	16 3	17 4	18 5	19 6	20 7	21 8	22 9	23 10	24 11	
JANUARY																											
HOURLY TEMPERATURES:		45.0	44.6	43.8	43.2	42.7	43.1	45.2	47.3	49.7	51.2	52.3	53.6	55.5	56.4	57.2	57.4	57.2	56.5	54.8	52.8	51.0	49.3	48.0	46.8		
HOURLY LOADS:	1	283	278	266	258	251	256	287	317	350	372	387	406	432	446	456	460	456	447	423	394	368	345	326	309	357	180059
FEBRUARY																											
HOURLY TEMPERATURES:		46.4	45.9	45.0	44.3	43.7	44.1	46.7	49.2	51.9	53.8	55.0	56.6	58.7	59.9	60.7	61.0	60.7	59.9	58.0	55.6	53.4	51.5	49.9	48.5		
HOURLY LOADS:	1	303	297	283	273	265	272	308	343	382	408	425	448	478	494	507	511	507	495	467	434	403	375	354	334	390	187310
MARCH																											
HOURLY TEMPERATURES:		47.7	47.2	46.1	45.3	44.6	45.1	48.0	50.9	54.0	56.2	57.6	59.4	61.9	63.2	64.2	64.5	64.2	63.3	61.0	58.3	55.8	53.5	51.8	50.2		
HOURLY LOADS:	1	321	314	299	287	278	285	327	367	412	442	462	488	523	542	556	560	556	543	511	472	437	405	380	357	422	232823
APRIL																											
HOURLY TEMPERATURES:		50.8	50.2	49.1	48.2	47.5	48.1	51.2	54.2	57.6	59.9	61.4	63.3	66.0	67.4	68.5	68.8	68.5	67.5	65.1	62.2	59.5	57.1	55.2	53.4		
HOURLY LOADS:	1	366	358	341	329	319	327	371	415	462	495	516	544	581	601	617	621	617	602	568	527	489	455	428	403	473	227053
MAY																											
HOURLY TEMPERATURES:		54.1	53.5	52.3	51.4	50.7	51.3	54.5	57.6	61.1	63.4	65.0	67.0	69.7	71.2	72.3	72.6	72.3	71.2	68.7	65.8	63.0	60.5	58.6	56.8		
HOURLY LOADS:	1	412	405	387	375	365	373	418	463	512	545	567	595	634	655	670	675	670	656	620	578	539	504	476	451	523	276012
JUNE																											
HOURLY TEMPERATURES:		57.5	56.9	55.6	54.6	53.8	54.4	57.9	61.3	65.1	67.6	69.3	71.5	74.5	76.0	77.2	77.6	77.2	76.1	73.4	70.2	67.2	64.5	62.4	60.4		
HOURLY LOADS:	1	460	452	433	420	408	417	467	515	568	605	628	659	701	724	741	746	741	725	687	641	599	560	530	503	580	306475
JULY																											
HOURLY TEMPERATURES:		59.8	59.2	57.8	56.8	56.0	56.6	60.3	63.8	67.7	70.4	72.1	74.4	77.4	79.1	80.3	80.7	80.3	79.2	76.4	73.0	69.9	67.1	64.9	62.9		
HOURLY LOADS:	1	494	485	466	451	440	449	500	550	606	643	668	700	744	767	785	790	785	768	728	681	637	597	566	537	618	296713
AUGUST																											
HOURLY TEMPERATURES:		59.3	58.7	57.3	56.3	55.5	56.1	59.7	63.2	67.1	69.7	71.4	73.7	76.8	78.4	79.6	80.0	79.6	78.5	75.7	72.4	69.3	66.5	64.3	62.3		
HOURLY LOADS:	1	486	477	458	444	433	442	493	542	597	634	659	691	734	757	775	780	775	759	719	672	628	589	558	530	610	336508
SEPTEMBER																											
HOURLY TEMPERATURES:		59.3	58.8	57.5	56.5	55.7	56.3	59.8	63.2	66.9	69.5	71.1	73.3	76.3	77.8	79.0	79.4	79.0	77.9	75.7	72.0	69.0	66.3	64.2	62.3		
HOURLY LOADS:	1	487	479	460	447	435	444	494	542	595	631	654	685	727	749	767	772	767	751	712	667	625	586	556	529	607	291202
OCTOBER																											
HOURLY TEMPERATURES:		55.2	54.7	53.4	52.5	51.8	52.4	55.6	58.8	62.3	64.8	66.2	68.2	71.0	72.4	73.6	73.9	73.6	72.5	70.0	67.0	64.2	61.7	59.8	58.0		
HOURLY LOADS:	1	428	421	403	390	380	388	434	479	529	562	584	613	652	673	689	694	689	674	638	596	557	521	493	468	540	285012
NOVEMBER																											
HOURLY TEMPERATURES:		49.0	48.5	47.4	46.6	45.9	46.4	49.4	52.3	55.4	57.6	59.0	60.8	63.3	64.7	65.7	66.0	65.7	64.8	62.5	59.7	57.2	54.9	53.1	51.5		
HOURLY LOADS:	1	340	333	318	306	296	304	346	387	432	462	482	508	544	563	577	582	577	564	531	493	457	424	399	376	442	211999
DECEMBER																											
HOURLY TEMPERATURES:		45.2	44.8	44.0	43.3	42.8	43.2	45.5	47.8	50.2	51.9	53.0	54.5	56.4	57.5	58.3	58.5	58.3	57.5	55.7	53.6	51.6	49.8	48.5	47.2		
HOURLY LOADS:	1	287	281	269	260	252	258	291	323	358	382	397	418	446	460	472	475	472	461	436	406	378	352	333	315	366	140507

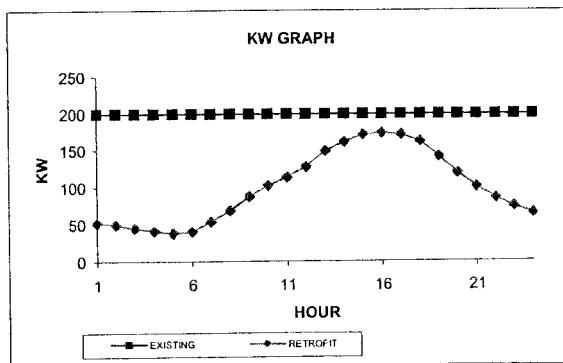
Table 12-8. VAV Cost Avoidance.

DAY TYPE: WEEKDAY			MONTH OF: JUNE					
PEAK DEMAND FACTOR: 1.0			COST: RATE SCH					
PEAK LOAD IN TONS: 790								
HOUR	TONS:	OSAT	% EXISTING	% CFM	--RETROFIT--			
			LOAD	KW/KWH	KWH			
					\$			
1	460	57.5	58%	200	\$10.12			
2	452	56.0	57%	200	\$10.12			
3	433	55.6	55%	200	\$10.12			
4	420	54.6	53%	200	\$10.12			
5	408	53.8	52%	200	\$10.12			
6	417	54.4	53%	200	\$10.12			
7	467	57.9	59%	200	\$10.12			
8	515	61.3	65%	200	\$11.62			
9	568	65.1	72%	200	\$11.62			
10	605	67.6	77%	200	\$11.62			
11	628	69.3	79%	200	\$11.62			
12	659	71.5	83%	200	\$11.62			
13	701	74.5	89%	200	\$17.55			
14	724	76.0	92%	200	\$17.55			
15	741	77.2	94%	200	\$17.55			
16	746	77.6	94%	200	\$17.55			
17	741	77.2	94%	200	\$17.55			
18	725	76.1	92%	200	\$17.55			
19	687	73.4	87%	200	\$11.62			
20	641	70.2	81%	200	\$11.62			
21	599	67.2	76%	200	\$11.62			
22	560	64.5	71%	200	\$10.12			
23	530	62.4	67%	200	\$10.12			
24	503	60.4	64%	200	\$10.12			
TOTAL/AVG. DAYS/MO.	580	65.9	0.73	4800	\$299.42			
TOTAL/MO.				0.73	2386	\$163.71	2414	\$135.71
							22	22
							53114.3	\$2,985.52

Table 12-8 (Cont'd).

PEAK DEM.	200	\$2,670.00	173	\$2,313.61	\$356.39
PART PEAK	200	\$740.00	141	\$521.86	\$218.14
MAX DEM	200	\$510.00	173	\$441.93	\$68.07
					<hr/> \$3,628.12
TOTAL COST AVOIDANCE:					

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER	
MAX PEAK:	\$13.35	\$0.00	
MAX PART PEAK:	\$3.70	\$3.65	
MAX DEMAND:	\$2.55	\$2.55	
ENERGY CHARGES:			
PEAK:	\$0.08773	\$0.00	
PARTIAL-PEAK:	\$0.05810	\$0.06392	
OFF-PEAK:	\$0.05059	\$0.05038	



percentage of the annual peak the loads will be at any given hour for a typical day in the month of June.

Going to the upper left hand corner of the large data portion of the table we can see that we have the hours per day listed, and alongside of it the cooling load in tons and the outside air temperature for this typical day in the month of June. By referring back to Table 12-7 we can see that the numbers in this column came directly off of Table 12-7.

Moving on to the next box in the data table we see that we have calculated a percent of peak load which is the hourly load in tons divided by the annual peak listed at the top of the page and we have also listed the existing kW/kWh of the air handling system fan for each hour of the day. Note that because the time periods are one hour in length the kW values shown multiplied by the one-hour duration of each time interval are exactly equal to the kilowatt-hours as well. Finally, in the "existing" data box we are able to calculate the kilowatt-hour cost by each hour of the day by applying the rate schedule shown in the lower left hand corner of the table according to the appropriate time of use period which applies. Note that the kilowatt-hour cost changes as we move through the different time of use periods.

Moving to the "retrofit" box, in the first column we list the percent cfm, which in this case is equal to the percent load, assuming a constant supply air temperature. There is a note which indicates that we have written the formulas to provide for a minimum of 50% supply air, meaning that in the winter months we will actually raise the supply air temperature so as to avoid dumping cold air on to the occupants' heads. As we can see, in the month of June we don't encounter the minimum air volume "floor" in this particular calculation since we are in a warmer month of the year. In the next column, we list kW/kWh for each hour of the day. This is based on an algorithm or direct measurements taken in the field. For example, it would be very easy to hang a kWh transducer on the variable speed drive, and watch the simultaneous outside air temperature or, alternatively, install an air flow measuring station or Pitot tube in the main supply duct and actually directly measure the percent cfm and the instantaneous kilowatt-hours consumed by the fan. If direct measurements are made, a very simple formula can be developed which relates the power draw of the supply fan to the percent cfm. Alternatively, the owner and the ESCo may agree to a stipulated formula which says that, for example, the supply fan's power varies according to the fan laws (with a minor adjustment for the fact that the system curve of the

air distribution system is constantly changing because the VAV dampers are closing off and thereby increasing the friction losses through the damper as the load in the space drops). Simply varying the speed in a constant volume system would result in the fan power varying according to the cube of the air flow. That is, if the airflow were reduced to 50%, the fan power would 0.53 or 0.125 of the original fan power. Generally for VAV systems an exponent in the range of 2 to 2.5 can be used for this equation and be reasonably accurate. Again, if a simplistic formula is not acceptable, short term field measurements can be performed and a more precise formula developed. For this spreadsheet example, a fan law equation using the exponent of 2.5 has been assumed. For example, for the first hour of the day, 0.58 cfm raised to the 2.5 power multiplied times the original fan kW of 200 results in a retrofit kW of 52 (all numbers shown are rounded so the math may not check perfectly). The bottom line here is that a whole range of possible direct measurements may be taken (kW, outside air temperature, actual cfm, etc.) and as little as one of these measurements might be used with a mutually agreed algorithm to establish the other value (or values) needed for the calculation of savings. To finish this data block, the hour-by-hour kilowatt-hour cost is again calculated by applying the hourly kWh to the rate schedule in the lower left hand corner of the spreadsheet.

Finally, in the upper part of the table, the difference, or “delta kWh,” is calculated by subtracting the retrofit kWh from the existing kWh and the savings in the cost of kilowatt-hours is similarly calculated.

The kilowatt-hours saved and the kilowatt-hour cost saved are totaled then for a typical day each month as shown. Because it is a typical weekday for each month and there are 22 weekdays for the month of June for this year, we then multiply by 22 to get the total monthly savings in kilowatt-hours and cost.

To complete the savings calculation we also need to include the value of the demand savings. As can be seen, the peak demand, the part-peak demand and the maximum demand are extracted from the time of use periods in each column, both for the existing and the retrofit cases. The existing cost is then calculated from the rate schedule, the retrofit demand costs are calculated similarly, and the savings in demand costs are shown in the right hand column. Finally, the total avoided cost is added up, totaling some \$3600 for the month of June.

As an added note, you will observe that on virtually every chart we have included a small graph. This is particularly helpful when trying to

explain the calculations to upper management and also as a method of error checking. If the graph does not look right, it is probably because there is something wrong with the data.

As mentioned previously, no attempt has been made in this example to show the “secondary” effect of heating and cooling savings by performing the variable air volume conversion. Remembering that Option A is intended to be a very simplistic approach and one in which the owner and the ESCo are intent on finding ways to agree rather than to contend, the heating and cooling savings may simply be stipulated as a ratio or factor multiplied times the fan power savings as calculated in this example. While heating savings will likely persist all year long, cooling savings will probably only occur during warm ambient temperature conditions because it is altogether likely that an outside air economizer already exists on the air handling system. This should be taken into account in the stipulation. Some hand calculations, or, a “generic” computer simulation might be performed using Trace or perhaps the DOE-2 program to establish typical ratios for each month of the year between VAV fan savings and cooling and heating savings. These calculations may ultimately be very similar to the hour-by-hour calculations used for Option B, which is discussed later in this chapter.

CHILLER RETROFIT USING OPTION A

For the chiller retrofit measurement and verification under Option A, we will employ method CH-A-02, spot metering. In order to implement this methodology we will do the following:

1. We will measure the existing chiller load versus outside air temperature for a short time and extrapolate to an annual load profile, or, alternatively, we will use a computer simulation program to establish an acceptable cooling load profile.
2. We will measure the new chiller kW/ton, possibly versus outside air temperature, for a short duration and apply this retrofit kW/ton to the annual load profile developed above.
3. We will calculate the units of energy saved by subtracting the post-retrofit consumption from the baseline condition.

4. We will calculate cost avoidance by multiplying kilowatt-hours saved and kW saved by appropriate unit costs.
5. For the variable speed pump we will do the measurement and verification exactly as was done for the VFD for the VAV retrofit.
6. For variable speed towers we will do likewise if fan power or control is changed as part of the retrofit, i.e., a variable fan drive system is installed.

Referring to Table 12-9, we can see that it is the same load profile table which was presented in Table 12-7. Again, the details of how this established are discussed in the appendix.

Moving on to Table 12-10, we can see that this table is very similar to Table 12-8 in that it shows the calculations for a weekday day type in the month of June. As in Table 12-7, the first box of data shows each hour of the day with the concurrent cooling load in tons and outside air temperature. This again, is pulled directly from the cooling load profile in Table 12-9.

The next box shows the existing energy use. First of all, a stipulated kW/ton for the existing chillers is shown in the table. This may be the manufacturer's original rating, it may be a measured value (still unlikely), or it may be the original manufacturer's rating with a slight adjustment for age and wear and tear of the machine. Again, it is unlikely that it is a measured value as we are using Option A, and the whole idea of Option A is to keep things simple and avoid the temptation of trying to develop a "1% answer to a 10% question." By multiplying the kW/ton times *the hourly tons we come up with the hourly kW/kWh, which is shown*. Using the rate schedule again, the hourly kilowatt-hour cost is then calculated.

Moving on to the next box, which contains the retrofit energy use and cost calculations, we can see that at a kW/ton of 0.50 has been stipulated in this case. If this were actually field-verified by measurements of the retrofit chiller's actual kW/ton with adjustments for air temperature, this number might vary according to the outside air temperature. Again, attempting to find a simplistic methodology, we have shown a stipulated value in this example. Once again, multiplying the stipulated kW/ton by the tonnage for each hour of the day, we able to calculate the kW/kWh for each hour of the day and apply the rate schedule to also calculate the hourly kilowatt-hour cost.

Table 12-9.

TITLE: XICOR/TES_SDY	SYS	WEEKDAY COOLING LOAD PROFILES AND HOURLY TEMPERATURES																									
		ON?	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Avg Load
0/1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
JANUARY																											
HOURLY TEMPERATURES:		45.0	44.6	43.8	43.2	42.7	43.1	45.2	47.3	49.7	51.2	52.3	53.6	55.5	56.4	57.2	57.4	57.2	56.5	54.8	52.8	51.0	49.3	48.0	46.8		
HOURLY LOADS:	1	283	278	266	258	251	256	287	317	350	372	387	406	432	446	456	460	456	447	423	394	368	345	326	309	357	180059
FEBRUARY																											
HOURLY TEMPERATURES:		46.4	45.9	45.0	44.3	43.7	44.1	46.7	49.2	51.9	53.8	55.0	56.6	58.7	59.9	60.7	61.0	60.7	59.9	58.0	55.6	53.4	51.5	49.9	48.5		
HOURLY LOADS:	1	303	297	283	273	265	272	308	343	382	408	425	448	478	494	507	511	507	495	467	434	403	375	354	334	390	187310
MARCH																											
HOURLY TEMPERATURES:		47.7	47.2	46.1	45.3	44.6	45.1	48.0	50.9	54.0	56.2	57.6	59.4	61.9	63.2	64.2	64.5	64.2	63.3	61.0	58.3	55.8	53.5	51.8	50.2		
HOURLY LOADS:	1	321	314	299	287	278	285	327	367	412	442	462	488	523	542	556	560	556	543	511	472	437	405	380	357	422	232823
APRIL																											
HOURLY TEMPERATURES:		50.8	50.2	49.1	48.2	47.5	48.1	51.2	54.2	57.6	59.9	61.4	63.3	66.0	67.4	68.5	68.8	68.5	67.5	65.1	62.2	59.5	57.1	55.2	53.4		
HOURLY LOADS:	1	366	358	341	329	319	327	371	415	462	495	516	544	581	601	617	621	617	602	568	527	489	455	428	403	473	227053
MAY																											
HOURLY TEMPERATURES:		54.1	53.5	52.3	51.4	50.7	51.3	54.5	57.6	61.1	63.4	65.0	67.0	69.7	71.2	72.3	72.6	72.3	71.2	68.7	65.8	63.0	60.5	58.6	56.8		
HOURLY LOADS:	1	412	405	387	375	365	373	418	463	512	545	567	595	634	655	670	675	670	656	620	578	539	504	476	451	523	276012
JUNE																											
HOURLY TEMPERATURES:		57.5	56.9	55.6	54.6	53.8	54.4	57.9	61.3	65.1	67.6	69.3	71.5	74.5	76.0	77.2	77.5	77.2	76.1	73.4	70.2	67.2	64.5	62.4	60.4		
HOURLY LOADS:	1	460	452	433	420	408	417	467	515	568	605	628	659	701	724	741	746	741	725	687	641	599	560	530	503	580	306475
JULY																											
HOURLY TEMPERATURES:		59.8	59.2	57.8	56.8	56.0	56.6	60.3	63.8	67.7	70.4	72.1	74.4	77.4	79.1	80.3	80.7	80.3	79.2	76.4	73.0	69.9	67.1	64.9	62.9		
HOURLY LOADS:	1	494	485	466	451	440	449	500	550	606	643	668	700	744	767	785	790	785	768	728	681	637	597	566	537	618	296713
AUGUST																											
HOURLY TEMPERATURES:		59.3	58.7	57.3	56.3	55.5	56.1	59.7	63.2	67.1	69.7	71.4	73.7	76.8	78.4	79.6	80.0	79.6	78.5	75.7	72.4	69.3	66.5	64.3	62.3		
HOURLY LOADS:	1	486	477	458	444	433	442	493	542	597	634	659	691	734	757	775	780	775	759	719	672	628	589	558	530	610	336508
SEPTEMBER																											
HOURLY TEMPERATURES:		59.3	58.8	57.5	56.5	55.7	56.3	59.8	63.2	66.9	69.5	71.1	73.3	76.3	77.8	79.0	79.4	79.0	77.9	75.2	72.0	69.0	66.3	64.2	62.3		
HOURLY LOADS:	1	487	479	460	447	435	444	494	542	595	631	654	685	727	749	767	772	767	751	712	667	625	586	556	529	607	291202
OCTOBER																											
HOURLY TEMPERATURES:		55.2	54.7	53.4	52.5	51.8	52.4	55.6	58.8	62.3	64.6	66.2	68.2	71.0	72.4	73.6	73.9	73.6	72.5	70.0	67.0	64.2	61.7	59.8	58.0		
HOURLY LOADS:	1	428	421	403	390	380	388	434	479	529	562	584	613	652	673	689	694	689	674	638	596	557	521	493	468	540	285012
NOVEMBER																											
HOURLY TEMPERATURES:		49.0	48.5	47.4	46.6	45.9	46.4	49.4	52.3	55.4	57.6	59.0	60.8	63.3	64.7	65.7	66.0	65.7	64.8	62.5	59.7	57.2	54.9	53.1	51.5		
HOURLY LOADS:	1	340	333	318	306	296	304	346	387	432	462	482	508	544	563	577	582	577	564	531	493	457	424	399	376	442	211999
DECEMBER																											
HOURLY TEMPERATURES:		45.2	44.8	44.0	43.3	42.8	43.2	45.5	47.8	50.2	51.9	53.0	53.0	54.5	56.4	57.5	58.3	58.5	58.3	57.5	55.7	53.6	51.8	49.8	48.5	47.2	
HOURLY LOADS:	1	287	281	269	260	252	258	291	323	358	382	397	418	446	460	472	475	472	461	436	406	378	352	333	315	366	140507

Table 12-10. Chiller Cost Avoidance.

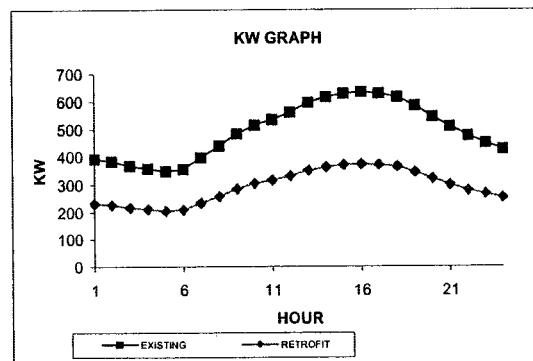
DAY TYPE: PEAK DEMAND FACTOR:			WEEKDAY 1.0			MONTH OF: COST:			JUNE RATE SCH		
HOUR	TONS:	OSAT	EXISTING			RETROFIT			DELTA KWH	DELTA KWH	
			KW/TON	KW/KWH	KWH	KW/TON	KW/KWH	KWH			
					\$			\$			
1	460	57.5	0.85	391	\$19.78	0.50	230	\$11.64	161	\$8.14	
2	452	56.0	0.85	384	\$19.44	0.50	226	\$11.43	158	\$8.00	
3	433	55.6	0.85	368	\$18.62	0.50	217	\$10.95	152	\$7.67	
4	420	54.6	0.85	357	\$18.06	0.50	210	\$10.62	147	\$7.44	
5	408	53.8	0.85	347	\$17.54	0.50	204	\$10.32	143	\$7.22	
6	417	54.4	0.85	354	\$17.93	0.50	209	\$10.55	146	\$7.38	
7	467	57.9	0.85	397	\$20.08	0.50	234	\$11.81	163	\$8.27	
8	515	61.3	0.85	438	\$25.43	0.50	258	\$14.96	180	\$10.47	
9	568	65.1	0.85	483	\$28.05	0.50	284	\$16.50	199	\$11.55	
10	605	67.6	0.85	514	\$29.88	0.50	303	\$17.58	212	\$12.30	
11	628	69.3	0.85	534	\$31.01	0.50	314	\$18.24	220	\$12.77	
12	659	71.5	0.85	560	\$32.54	0.50	330	\$19.14	231	\$13.40	
13	701	74.5	0.85	596	\$52.27	0.50	351	\$30.75	245	\$21.52	
14	724	76.0	0.85	615	\$53.99	0.50	362	\$31.76	253	\$22.23	
15	741	77.2	0.85	630	\$55.26	0.50	371	\$32.50	259	\$22.75	
16	746	77.6	0.85	634	\$55.63	0.50	373	\$32.72	261	\$22.91	
17	741	77.2	0.85	630	\$55.26	0.50	371	\$32.50	259	\$22.75	
18	725	76.1	0.85	616	\$54.06	0.50	363	\$31.80	254	\$22.26	
19	687	73.4	0.85	584	\$33.93	0.50	344	\$19.96	240	\$13.97	
20	641	70.2	0.85	545	\$31.66	0.50	321	\$18.62	224	\$13.03	
21	599	67.2	0.85	509	\$29.58	0.50	300	\$17.40	210	\$12.18	
22	560	64.5	0.85	476	\$24.08	0.50	280	\$14.17	196	\$9.92	
23	530	62.4	0.85	451	\$22.79	0.50	265	\$13.41	186	\$9.38	
24	503	60.4	0.85	428	\$21.63	0.50	252	\$12.72	176	\$8.91	
TOTAL/AVG.	580	65.9	0.85	11841	\$768.51	0.50	6965	\$452.07	4876	\$316.45	
									22	22	
TOTAL/MO.											
TOTAL/MO.									107261	\$6,961.81	

(Continued)

Table 12-10.

PEAK DEM.	634	\$8,465.24	373	\$4,979.55	\$3,485.69
PART PEAK	584	\$2,160.62	344	\$1,270.95	\$889.67
MAX DEM	634	\$1,616.96	373	\$951.15	\$665.81
TOTAL COST AVOIDANCE:					<u>\$12,002.97</u>

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER	
MAX PEAK:	\$13.35	\$0.00	
MAX PART PEAK:	\$3.70	\$3.65	
MAX DEMAND:	\$2.55	\$2.55	
ENERGY CHARGES:			
PEAK:	\$0.08773	\$0.00	
PARTIAL-PEAK:	\$0.05810	\$0.06392	
OFF-PEAK:	\$0.05059	\$0.05038	



In the last box, the hourly savings in units of energy (kWh) and the cost of the kWh are shown. These are then totaled for a typical day and multiplied by the number of days per month to come up with a monthly total for kilowatt-hours and kilowatt-hour cost.

Similarly to the VAV retrofit shown in Table 12-8, we also calculate the existing and retrofit cost for demand, the savings in demand and the total avoided cost for the month of slightly more than \$12,000.

Once again, a graph is shown in order to better understand what is actually happening in the building and the calculations that result from it.

OPTION A VERIFICATION

Hammering the point home, perhaps once again, the “verification” part of “measurement and verification” is frequently forgotten about, it has been said that if we can simply do the verification portion of M&V we would solve 90% of the problems relating to poor performance of energy retrofit work.

Measurement means that we go out and take measurements in the field. Verification, by contrast, means that we go out and satisfy to ourselves that the retrofit was actually completed, including:

- We verify that the proper equipment and system were installed. In other words, did we get the right stuff?
- We verify that the systems and equipment are performing according to their intent and/or these specifications. In other words, is the right stuff working correctly? Or in other words, does the retrofit have the potential to save energy?
- Finally, on a regular periodic basis (perhaps annually) we verify that the equipment continues to perform during the entire term of the contract.

The idea of proving to ourselves that the retrofit has the potential to save energy is rather critical, especially in retrofits that involved somewhat complicated temperature or automatic control systems. We have commonly observed, for example, that variable air volume and variable flow chilled water systems frequently have their differential pressure

transmitters incorrectly installed or incorrectly hooked up to the control system. It is not all that uncommon to find that the differential pressure transmitter has been installed very close to the discharge of the fan or the pump, meaning that it will never be capable of seeing the reduced friction losses in the system at low flow, which can only be sensed at the end of the system and therefore we will never be able to adjust the speed of the fan or pump to take advantage of the decreased friction losses in the air or water distribution system. To prove this phenomenon to oneself requires that you create a system diagram and consider the system operation at high and low load conditions with the differential pressure transmitter adjacent to the fan or pump and at the end of the system. By doing so, and understanding how the control system operates, this phenomenon becomes abundantly clear.

OPTION A ISSUES

As has been demonstrated by our example, there are a number of characteristics of the use of Option A which must be taken into consideration, as follows:

- The savings using Option A are determined based on measured performance and stipulated operation. For example, this means that no credit or risk is experienced for changing the hours of operation of a lighting system.
- Option A is limited in that it will only tell you a little bit of information about the actual operation of the retrofit, since the actual operation of the retrofit is only observed for a short period following its installation and on a periodic basis. If you happen to only look at the retrofit when it is performing well you might miss the fact that it is not performing well the rest of the time. This is something akin to dozing off at a stoplight while driving home late at night and only opening your eyes periodically to see that the light is still red, missing the fact that other half of the time the light is green.
- Option A generally ignores interactions between systems. For example, by performing a lighting retrofit we are probably reducing

the cooling load on the building, yet because we are using a stipulated cooling load profile, we will not capture the extra savings in reduced cooling from the lighting retrofit. Of course, this interaction can be stipulated as well by employing the output a computer simulation or other manual calculation methodology agreed to by both parties. By contrast, in this example for the VAV retrofit, if the fan power was measured as it relates to outside air temperature and this algorithm was used (as opposed to using a percent cfm or percent cooling load algorithm) then the additional reduced fan power resulting from a decrease in the cooling load from lighting retrofit would be captured by this methodology.

- Option A will tell you whether the equipment is still performing to specification.
- A key advantage of Option A is that it can be very inexpensive.
- Because of the nature of Option A, it is frequently considered to be a performance warranty.

OPTION B: MEASURED PERFORMANCE, MEASURED OPERATION

For this project specific example, the procedures are the same as Option A, except that we add continuous measurement of post-installation energy use.

The savings are determined utilizing end-use measured data, generally throughout the term of the contract. ASHRAE refers to this as “retrofit isolation” in document GPC-14P.

OPTION B, LIGHTING

For lighting under Option B, we will use method LE-B-02, continuous metering of circuits. In order to accomplish this, we will:

- Record the existing lighting power at floor panels or a main riser, if possible. In some buildings we have surveyed, a bus riser provides power up through the building with bus-tap switches at each

floor to serve 277 volt lighting panels on each floor. In some buildings, there's a separate low-voltage (120 volt) riser for desktop and "plug" loads. In such buildings, it would be possible to simply record the power consumption in the riser and by doing so capture all of the power going in to the lighting systems in the building.

- We will install kilowatt-hour (kWh) transducers on each floor panel (or again, the main riser, if possible) and measure post-retrofit energy use.
- We will calculate the energy units saved by comparing the post-retrofit energy use to baseline energy use.
- Cost avoidance (dollar savings) will be calculated by multiplying kilowatt-hours saved and kW saved by their respective unit costs.

Referring to Table 12-11, we see once again a somewhat familiar looking spreadsheet. The first thing you will notice is that this is a weekday spreadsheet. The second thing that you should notice is that it is not a typical weekday, but a specific weekday, i.e., a single specific day. In the first data block you will notice that we have the hour of the day. In the next data block, you will notice that we have the existing energy consumption. Looking at the data, it is clear that this is typical data for a weekday developed from the pre-retrofit measured data gathered during the feasibility study. Generally speaking, this would probably be the average of a number of representative continuous weekday measurements. Another point to make note of, is the fact that since this is pre-retrofit typical data, it will not change as these measurement and verification reports are produced on an ongoing basis. This data will be the same for every report for every future day that is measured and verified.

Moving on to the next data block, you will notice that this block contains the post-retrofit measured energy use. This is the actual recorded instantaneous power for a specific day, hour by hour. Since it is actual data, it will be different for every individual post-retrofit day. This should stimulate recognition on the reader's part that Option B will involve the gathering, reduction and tabulation of a potentially enormous amount of data.

As we can see in the next block, the spreadsheet is calculating the hour-by-hour difference (or delta) savings in kilowatt-hours. By

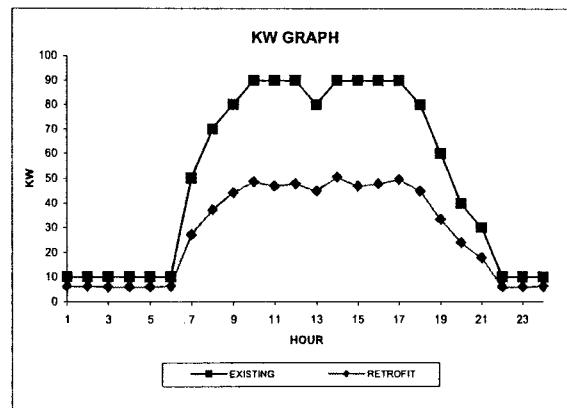
Table 12-11. Lighting Cost Avoidance.

DAY TYPE:	WEEKDAY	DATE:	06/09/98				
LOCATION:	1'ST FLOOR	COST:	RATE SCH				
HOUR	EXISTING		RETROFIT		DELTA	DELTA	
	KW/KWH	KWH	KW/KWH	KWH	KWH	\$	
1		10	\$0.51		6	\$0.31	
2		10	\$0.51		6	\$0.31	
3		10	\$0.51		6	\$0.30	
4		10	\$0.51		6	\$0.30	
5		10	\$0.51		6	\$0.30	
6		10	\$0.51		6	\$0.31	
7		50	\$2.53		27	\$1.37	
8		70	\$4.07		37	\$2.16	
9		80	\$4.65		44	\$2.56	
10		90	\$5.23		49	\$2.82	
11		90	\$5.23		47	\$2.72	
12		90	\$5.23		48	\$2.77	
13		80	\$7.02		45	\$3.93	
14		90	\$7.90		50	\$4.42	
15		90	\$7.90		47	\$4.11	
16		90	\$7.90		48	\$4.18	
17		90	\$7.90		50	\$4.34	
18		80	\$7.02		45	\$3.93	
19		60	\$3.49		34	\$1.95	
20		40	\$2.32		24	\$1.39	
21		30	\$1.74		18	\$1.03	
22		10	\$0.51		6	\$0.30	
23		10	\$0.51		6	\$0.30	
24		10	\$0.51		6	\$0.31	
TOTAL/AVG.		1210	\$84.66	665	\$46.41	546	\$38.24

(Continued)

Table 12-11.

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:
		01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER
MAX PEAK:	\$13.35	\$0.00
MAX PART PEAK:	\$3.70	\$3.65
MAX DEMAND:	\$2.55	\$2.55
ENERGY CHARGES:		
PEAK:	\$0.08773	\$0.00
PARTIAL-PEAK:	\$0.05810	\$0.06392
OFF-PEAK:	\$0.05059	\$0.05038



(Continued)

multiplying by the appropriate rate schedule from the lower part of the figures/spreadsheet, we also can calculate the hour-by-hour savings in the cost of kilowatt-hours. As we can see, for the day 6/9/98 the avoided cost for lighting retrofit is \$38.24 for a single day.

There will be 30 of these spreadsheets for the month of June, along with a summary spreadsheet. Since demand is generally charged to a building owner on the basis of the peak demand during the month, we will address the demand savings and its avoided cost only on the summary spreadsheet for the month.

Finally, in Table 12-11 note that we have included a little graph showing the baseline and post-retrofit hourly energy use.

Table 12-12. This table shows the summary of the lighting cost avoidance for the month. It will reiterate the kilowatt-hour and kilowatt-hour cost savings and present the demand and demand cost avoidance as well.

Note that at the top of this spreadsheet we have employed a peak demand factor. Since we are looking at an individual retrofit, and not the building in its entirety, it is altogether possible that a reduction in the peak demand of any one load in the building will not coincide with and contribute directly to the building's overall peak electrical demand in its entirety. That is, the building may peak when the lighting demand savings are only 90% of the maximum lighting demand savings that occurs during the day. A factor like this is generally negotiable and may be demonstrated by data gathered during the feasibility study, or it may be stipulated as a result of a process of a negotiation between the owner and the performance contractor, perhaps based on a building simulation model.

Looking at the first data block, we can see that the days of the month are listed and the weekend days are highlighted. In the next data block, we have the existing energy consumption, which once again is typical data gathered during the feasibility study. These numbers are individual day totals, and by cross-referencing this Table with Table 12-11, you will see that this data is simply lifted from the individual day spreadsheets and transferred to this summary spreadsheet. The next data block is our post-retrofit energy use data, in this case displayed based upon the local utility company rate structure that provides for a "peak" (otherwise known as "on-peak"), "part-peak," and, finally "max" or maximum demand. In this particular rate schedule, the "on-peak" period is a noon to six time window, the "part-

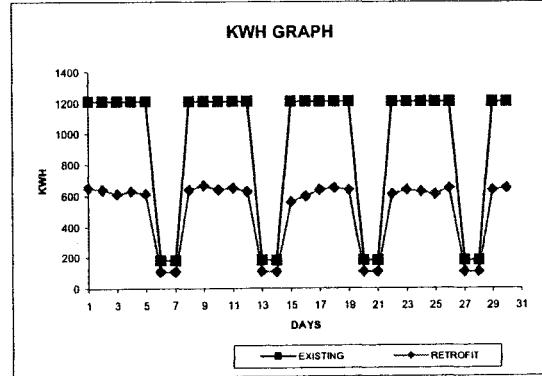
Table 12-12. Lighting Cost Avoidance Summary.

PEAK DEMAND FACTOR: LOCATION:		1.0 1'ST FLOOR		MONTH OF: COST:		Jun-98 RATE SCH	
DAY	EXISTING	RETROFIT				DELTA	DELTA
	KWH \$	KWH \$	PEAK KW	PART KW	MAX KW	KWH \$	KWH \$
1	1210	\$84.66		49	32	49	652 \$45.48
2	1210	\$84.66		48	31	48	638 \$44.55
3	1210	\$84.66		46	33	46	612 \$42.70
4	1210	\$84.66		47	32	47	625 \$43.63
5	1210	\$84.66		46	30	46	612 \$42.70
6	182	\$12.70		8	5	8	106 \$7.43
7	182	\$12.70		8	5	8	106 \$7.43
8	1210	\$84.66		48	32	48	638 \$44.55
9	1210	\$84.66		50	34	50	665 \$46.41
10	1210	\$84.66		48	33	48	638 \$44.55
11	1210	\$84.66		49	30	49	652 \$45.48
12	1210	\$84.66		47	32	47	625 \$43.63
13	182	\$12.70		8	5	8	106 \$7.43
14	182	\$12.70		8	5	8	106 \$7.43
15	1210	\$84.66		42	33	42	559 \$38.98
16	1210	\$84.66		45	30	45	599 \$41.77
17	1210	\$84.66		48	34	48	638 \$44.55
18	1210	\$84.66		49	31	49	652 \$45.48
19	1210	\$84.66		48	34	48	638 \$44.55
20	182	\$12.70		8	5	8	106 \$7.43
21	182	\$12.70		8	5	8	106 \$7.43
22	1210	\$84.66		46	30	46	612 \$42.70
23	1210	\$84.66		48	33	48	638 \$44.55

(Continued below)

24	1210	\$84.66	47	32	47	625	\$43.63	585	\$41.03
25	1210	\$84.66	46	31	46	612	\$42.70	598	\$41.96
26	1210	\$84.66	49	33	49	652	\$45.48	558	\$39.18
27	182	\$12.70	8	5	8	106	\$7.43	75	\$5.27
28	182	\$12.70	8	5	8	106	\$7.43	75	\$5.27
29	1210	\$84.66	48	33	48	638	\$44.55	572	\$40.11
30	1210	\$84.66	49	30	49	652	\$45.48	558	\$39.18
31							\$0.00		\$0.00
TOTAL/MAX.	28072	\$ 1,964.11	50	34	50	14723	\$1,027.52	13349	\$936.59
PEAK DEM.	90	\$ 1,201.50				50	\$ 667.50		\$534.00
PART PEAK	60	\$ 222.00				34	\$ 125.80		\$96.20
MAX DEM	90	\$ 229.50				50	\$ 127.50		\$102.00
TOTAL COST AVOIDANCE:									\$1,668.79

RATE SCHEDULE: PG&E E19S	EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER
MAX PEAK:	\$13.35	\$0.00
MAX PART PEAK:	\$3.70	\$3.65
MAX DEMAND:	\$2.55	\$2.55
ENERGY CHARGES:		
PEAK:	\$0.08773	\$0.00
PARTIAL-PEAK:	\$0.05810	\$0.06392
OFF-PEAK:	\$0.05059	\$0.05038



peak" is the morning and early evening time windows, and the maximum demand is a number which is taken from any time during the previous month, regardless of the time of day. This table also reiterates the post-retrofit kilowatt-hours and kilowatt-hour cost avoidance. In the next data block the kilowatt-hour savings (delta kilowatt-hours) and kilowatt-hour cost avoidance are displayed as the total values for each individual day from the prior spreadsheet (Table 12-11).

Below each of these data blocks are listed totals, or maximum values, lifted out of the column of figures. All the figures shown are totals except under the demand columns, where the maximum value for the peak, part-peak and maximum kW columns are brought to the bottom. Looking at the totals, for example, at the far right we can see that the kilowatt-hour cost avoidance total for the month is some \$936.59.

Farther down on this table we see that we are dealing with changes in demand and the resulting the cost avoidance. First of all, the existing peak, part-peak and maximum demand are listed from the typical data from any of the individual day spreadsheets (remembering that the typical data is an average and will remain the same throughout the life of the project). These demand values have their respective current utility rates applied from the rate schedule data at the bottom of the table. Checking one of these numbers, we can see that the peak demand value of 90 kW multiplied by the summer demand charge for peak demand of \$13.35 per kW equals \$1201.50.

Moving to the right, we can see that the maximum values from the demand columns are brought down and positioned opposite their respective baseline values. The rate schedules for demand charges are again applied and the post-retrofit cost of demand is established. Finally, all the way to the right, the difference in the baseline cost of demand is contrasted with the post-retrofit cost of demand (\$1202.50 less \$667.50), showing an avoided peak demand cost of \$534. Doing this same calculation for part-peak and maximum demand and totaling the three together we see that the demand savings cost avoidance for the month of June was \$1668.79.

Once again, a graph is added to the spreadsheet so that the data can be visualized and obvious errors detected. Notice that the typical data provides a nice flat weekday graph, whereas the actual data is different for every week.

OPTION B VARIABLE AIR VOLUME RETROFIT

For the VAV retrofit we will use method VSD-B-01—continuous metering. We will track the fan energy and the heating energy, and, as will be discussed in the following, the cooling energy savings will be captured in the measurement and verification at the chiller.

Regarding the fan energy, we will measure the existing motor load and/or load profile during the feasibility study. We will install a kilowatt-hour transducer (or transducers) on each variable frequency drive. And we will measure the post-retrofit fan energy use. We will calculate energy units saved by comparing the post-retrofit energy use to the baseline or pre-retrofit energy use. Cost avoidance will be calculated by multiplying the units of kW and kilowatt-hours saved by the appropriate unit cost.

For the heating energy, we will:

- Spot-measure the existing air handling unit airflow and record its supply air temperature. This data will then be extrapolated to an annual energy use profile employing a spreadsheet or other building simulation/energy use analysis software.
- We will measure the post-retrofit supply air temperature and the VFD speed concurrently. This assumes that through some spot measurements during the post-retrofit period we will be able to devise a simplistic algorithm that defines the relationship between VFD speed and CFM. Alternatively, it would also be possible to install an airflow measuring station or perhaps just a simple Pitot tube in the main discharge duct. Any of these measurement methodologies is potentially workable and acceptable to the parties.
- We will calculate the energy units saved by comparing the post-retrofit energy use to the baseline or pre-retrofit energy use.
- Finally, we will calculate cost avoidance from the heating energy units saved multiplied by the appropriate utility rate.

Fan Energy

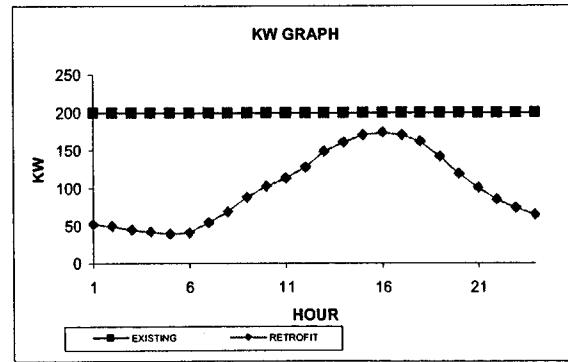
Table 12-13. Referring to the next table, we can see that this is a weekday record of the (fan energy) cost avoidance achieved by the variable air volume retrofit.

Table 12-13. VAV Cost Avoidance.

DAY TYPE:	WEEKDAY	DATE: COST:	06/09/98 RATE SCH				
HOUR	EXISTING		RETROFIT		DELTA	DELTA	
	KW/KWH	KWH	KW/KWH	KWH	KWH	KWH	
1		200 \$10.12		52 \$2.62	148	\$7.50	
2		200 \$10.12		50 \$2.51	150	\$7.61	
3		200 \$10.12		44 \$2.25	156	\$7.87	
4		200 \$10.12		41 \$2.09	159	\$8.03	
5		200 \$10.12		38 \$1.94	162	\$8.18	
6		200 \$10.12		40 \$2.05	160	\$8.07	
7		200 \$10.12		54 \$2.72	146	\$7.40	
8		200 \$11.62		69 \$3.99	131	\$7.63	
9		200 \$11.62		88 \$5.09	112	\$6.53	
10		200 \$11.62		103 \$5.96	97	\$5.66	
11		200 \$11.62		113 \$6.55	87	\$5.07	
12		200 \$11.62		127 \$7.39	73	\$4.23	
13		200 \$17.55		148 \$13.01	52	\$4.53	
14		200 \$17.55		161 \$14.11	39	\$3.44	
15		200 \$17.55		170 \$14.95	30	\$2.60	
16		200 \$17.55		173 \$15.20	27	\$2.34	
17		200 \$17.55		170 \$14.95	30	\$2.60	
18		200 \$17.55		161 \$14.16	39	\$3.39	
19		200 \$11.62		141 \$8.19	59	\$3.43	
20		200 \$11.62		119 \$6.89	81	\$4.73	
21		200 \$11.62		100 \$5.82	100	\$5.80	
22		200 \$10.12		85 \$4.28	115	\$5.84	
23		200 \$10.12		74 \$3.73	126	\$6.39	
24		200 \$10.12		65 \$3.27	135	\$6.84	
TOTAL/AVG.		4800	\$299.42	2386	\$163.71	2414	\$135.71

(Continued below)

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER	
MAX PEAK:	\$13.35	\$0.00	
MAX PART PEAK:	\$3.70	\$3.65	
MAX DEMAND:	\$2.55	\$2.55	
ENERGY CHARGES:			
PEAK:	\$0.08773	\$0.00	
PARTIAL-PEAK:	\$0.05810	\$0.06392	
OFF-PEAK:	\$0.05059	\$0.05038	



Again, the data blocks are very similar and this is a spreadsheet for a specific day, that being June 9, 1998.

Looking at the first data block, we can see that the hour of the day is displayed. Looking at the next data block we can see that the existing hourly kW and kilowatt-hours are shown (remembering that this is a constant volume air handling system prior to retrofit), and applying the appropriate rate schedule, we have tabulated the hourly cost of kilowatt-hours.

Moving on to the next data block, we see that the post-retrofit data is displayed. Now that a variable frequency drive has been installed on the supply fan, and the individual zone dampers adjust their airflow according to their actual need, we can see that the hourly electrical demand for the supply fan varies significantly over a 24-hour period. Applying the rate schedule we calculate the hourly post-retrofit cost of kilowatt-hours. In the next data block, we once again display the savings in units of kilowatt-hours, and the avoided cost for each hour of this day. And, as we can see, the VAV kilowatt-hour cost avoidance for this specific day is \$135.71.

Once again, notice that there is no analysis of demand charges on this page, as there will be thirty of these pages and demand will be dealt with on the monthly summary page. Also note, that the graph clearly depicts the changing power draw of the supply fan over the 24-hour period, contrasted to the original constant power draw system.

Table 12-14. As we can see, this is the monthly summary spreadsheet for the VAV conversion (fan energy) cost avoidance.

Again, we are showing daily totals, including the existing typical kilowatt-hour and kilowatt-hour cost data, the retrofit demand for each of the time of use periods, and reiteration of the kilowatt-hours saved ("delta kWh") and the kilowatt-hour cost avoidance ("delta kWh \$") from each of the daily spreadsheets. Note that we use very cryptic labels for the columns of data so as to make the spreadsheets as compact as possible. In a good M&V plan, each spreadsheet would be annotated to explain the meaning of these cryptic terms.

There is an error in this data that astute readers may have already noted. The error will be explained a couple of paragraphs further down, and you may want to examine the data now to see if you can detect it.

Once again, totals and maximums from the columns are gathered and, for example, our total kilowatt-hour cost avoidance for the month of June is \$5027.58. We also deal with demand costs at this point in the

Table 12-14. VAV Cost Avoidance Summary.

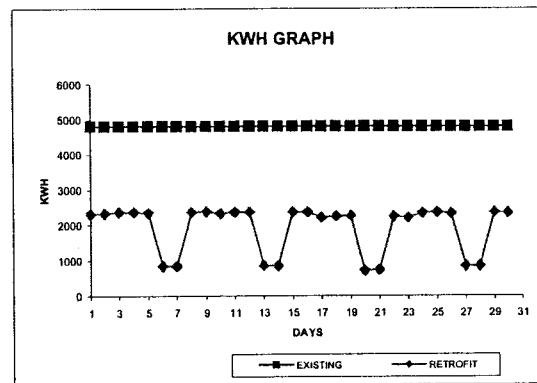
PEAK DEMAND FACTOR:	1.0		MONTH OF:			Jun-98		
			COST:		RATE SCH			
DAY	EXISTING-----		-----RETROFIT-----			DELTA	DELTA	
	KWH	KWH	PEAK	PART	MAX	KWH	KWH	
		\$	KW	KW	KW		\$	
1	4800	\$299.42		168	137	168	2317	\$158.98
2	4800	\$299.42		169	138	169	2331	\$159.92
3	4800	\$299.42		171	140	171	2358	\$161.82
4	4800	\$299.42		172	136	172	2372	\$162.76
5	4800	\$299.42		170	139	170	2345	\$160.87
6	4800	\$299.42		60	47	60	828	\$56.78
7	4800	\$299.42		61	48	61	841	\$57.72
8	4800	\$299.42		172	136	172	2372	\$162.76
9	4800	\$299.42		173	141	173	2386	\$163.71
10	4800	\$299.42		169	138	169	2331	\$159.92
11	4800	\$299.42		172	136	172	2372	\$162.76
12	4800	\$299.42		171	140	171	2358	\$161.82
13	4800	\$299.42		62	48	62	855	\$58.67
14	4800	\$299.42		61	49	61	841	\$57.72
15	4800	\$299.42		171	140	171	2358	\$161.82
16	4800	\$299.42		172	136	172	2372	\$162.76
17	4800	\$299.42		160	138	160.35	2212	\$151.74
18	4800	\$299.42		162	140	162.35	2239	\$153.63
19	4800	\$299.42		163	136	163.35	2253	\$154.58
20	4800	\$299.42		51	48	51	708	\$48.59
21	4800	\$299.42		53	48	53	736	\$50.49
22	4800	\$299.42		162	140	162.35	2239	\$153.63
23	4800	\$299.42		160	138	160.35	2212	\$151.74
24	4800	\$299.42		170	139	170	2345	\$160.87
25	4800	\$299.42		171	140	171	2358	\$161.82

(Continued)

Table 12-14.

26	4800	\$299.42	169	138	169	2331	\$159.92	2469	\$139.50
27	4800	\$299.42	61	50	61	841	\$57.72	3959	\$241.70
28	4800	\$299.42	60	49	60	828	\$56.78	3972	\$242.64
29	4800	\$299.42	171	140	171	2358	\$161.82	2442	\$137.60
30	4800	\$299.42	170	139	170	2345	\$160.87	2455	\$138.55
31							\$0.00		\$0.00
TOTAL/MAX.	144000	\$ 8,982.60	173	141	173	57643	\$3,955.02	86357	\$5,027.58
PEAK DEM.	200	\$ 2,670.00				173	\$2,309.55		\$360.45
PART PEAK	200	\$ 740.00				141	\$ 521.70		\$218.30
MAX DEM	200	\$ 510.00				173	\$ 441.15		\$68.85
TOTAL COST AVOIDANCE:									\$5,675.18

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER	
MAX PEAK:	\$13.35	\$0.00	
MAX PART PEAK:	\$3.70	\$3.65	
MAX DEMAND:	\$2.55	\$2.55	
ENERGY CHARGES:			
PEAK:	\$0.08773	\$0.00	
PARTIAL-PEAK:	\$0.05810	\$0.06392	
OFF-PEAK:	\$0.05059	\$0.05038	



spreadsheet, similar to what was done for the lighting retrofit. The typical demand values are shown, with their utility rate applied to them to provide a baseline or existing monthly cost, the actual post-retrofit data is analyzed for the current cost of demand, and the cost avoidance for the reduction in demand charges is shown at the far right (adding some \$600+ to the total avoided cost).

While some of the graphs that we have shown you on these tables may have seemed rather un-illuminating, this one reveals an interesting aspect of the retrofit, which should probably be characterized as synergy. Constant volume reheat HVAC systems are notable for the fact that if internal heat gain from the space is removed, the reheat coils will replace that heat gain with heat from the building heating system to maintain a constant cooling rate in this constant volume type of system. What that means is that if the space is lightly occupied during the weekends, there are no savings in the HVAC system as a result of that reduced occupancy. However, once a conversion to variable air volume is effected, the system can now respond to changes in the loads in the space and, as we can see from the graph on Table 12-14, the fan power is significantly reduced on the weekends when the building is lightly occupied. This is another error checking opportunity, as the absence of this fan power dip on the weekends could indicate a control system failure or a mis-programming of a digital control system.

Astute readers will have noticed that the “existing” daily cost for kWh is in error as should be lower on weekend days since there is no “on-peak” period on weekend days in most time-of-use rate schedules.

Heating Energy

Table 12-15. This is the table where we “separate the men from the boys.” This figure accounts for the heating cost avoidance resulting from the variable air volume retrofit. Once again, the figure shows a weekday analysis for a specific weekday, and shows hour-by-hour existing and retrofit data. Notice that in the second data block, we are showing typical existing CFM and supply air temperature (SAT) data. In the next data block, we are showing actual CFM and actual post-retrofit supply air temperature data. Readers will note that the supply air temperature data is displayed as being constant throughout this table. However, it may actually be that the VAV retrofit control system incorporates some supply air reset during the winter months, say to an upper value of 65 degrees (to avoid “dumping” cold air on the building occupants).

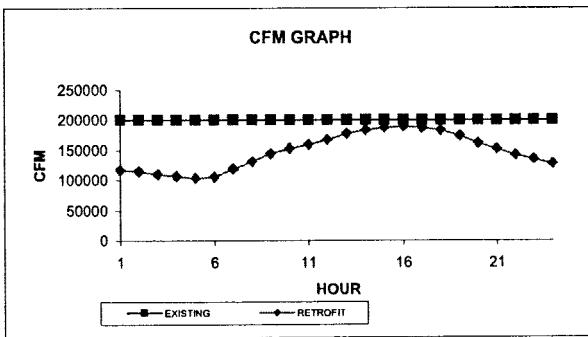
Table 12-15. VAV Heating Cost Avoidance.

DAY TYPE: BOILER EFFICIENCY: SPACE TEMP:	WEEKDAY 80% 72	DATE: COST:	06/09/98 RATE SCH				
HOUR	EXISTING		RETROFIT		DELTA BTU	*DELTA THERMS	DELTA THERMS
	CFM	SAT	CFM	SAT			\$
1	200000	60	116456	60	1,082,734	14	\$12.97
2	200000	60	114430	60	1,108,982	14	\$13.30
3	200000	60	109620	60	1,171,322	15	\$14.08
4	200000	60	106329	60	1,213,975	15	\$14.61
5	200000	60	103291	60	1,253,347	16	\$15.10
6	200000	60	105570	60	1,223,818	15	\$14.73
7	200000	60	118228	60	1,059,767	13	\$12.68
8	200000	60	130380	60	902,278	11	\$10.71
9	200000	60	143797	60	728,385	9	\$8.54
10	200000	60	153165	60	606,987	8	\$7.02
11	200000	60	158987	60	531,524	7	\$6.08
12	200000	60	166835	60	429,813	5	\$4.81
13	200000	60	177468	60	292,010	4	\$3.09
14	200000	60	183291	60	216,547	3	\$2.14
15	200000	60	187595	60	160,770	2	\$1.45
16	200000	60	188861	60	144,365	2	\$1.24
17	200000	60	187595	60	160,770	2	\$1.45
18	200000	60	183544	60	213,266	3	\$2.10
19	200000	60	173924	60	337,944	4	\$3.66
20	200000	60	162278	60	488,871	6	\$5.55
21	200000	60	151646	60	626,673	8	\$7.27
22	200000	60	141772	60	754,633	9	\$8.87
23	200000	60	134177	60	853,063	11	\$10.10
24	200000	60	127342	60	941,651	12	\$11.21
TOTAL/AVG.	200000	60	146941	60	16,503,494	206	\$192.76

* THERMS = BTU DIVIDED BY BOILER EFFICIENCY DIVIDED BY 100,000.

(Continued below)

RATE SCHEDULE: GNR1	EFFECTIVE DATE:	12/05/97
GAS CHARGES (per THERM)	SUMMER	WINTER
TOTAL CHARGE:	\$0.56406	\$0.73848



Moving on, we can see in the next data block there are three columns entitled “delta Btu,” “delta therms,” and “delta therms \$.” For the moment we will defer addressing how delta Btu is established, except only to say that this is a fairly complicated calculation but it is literally the amount the heating energy in Btus that is saved by reducing the total airflow in the system by converting it to variable air volume. Delta therms (as footnoted on the table), is achieved by dividing Btus by 100,000, which is the conversion from Btu to therms. Finally, delta therms \$ is simply the product of multiplying delta therms by the appropriate utility rate schedule, shown on the lower left hand corner of the table. As we can see in the table, the total heating avoided cost is \$192.76 for this specific day.

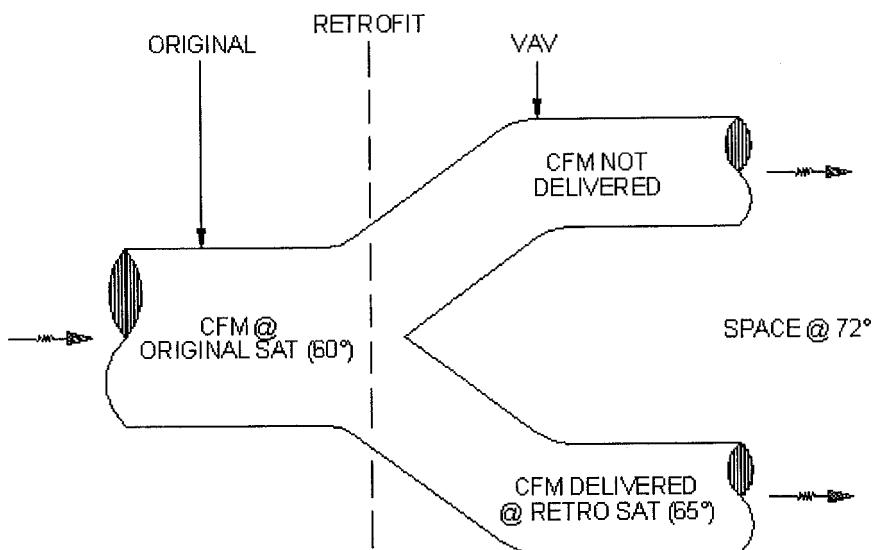
Referring to Figure 12-1, we will discuss how the calculation of delta Btu is accomplished in Table 12-15. In truth, to be a rigorous energy engineer you need to be able to perform some “mental gymnastics” in order to visualize and then calculate the results of performing certain energy retrofit work. The conversion of an air handling system to variable volume is one that represents a relatively great opportunity for experiencing mental gymnastics, as we will see in the following discussion.

Again, referring to Figure 12-1, we can see that in order to understand the energy units saved by converting a system to variable air volume, it is helpful to imagine the stream of air passing through the air handling system both before and after the retrofit is accomplished. Further, it is helpful to imagine that the process of converting the system has more or less “split” the original airstream into two new airstreams, those being the stream of air that continues to be delivered (cfm_d) and the stream of air that is not delivered (cfm_{nd}) any longer.

As we can see in the figure, we are assuming in our discussion that the original supply air temperature is 60 degrees, the space temperature is 72 degrees, and the wintertime supply air temperature of the air actually delivered to the space has been reset to 65 degrees.

The energy savings, then, consist of two components: the energy saved by not reheating the air which is no longer being delivered, and the energy saved by not reheating the air which is being delivered (from its normal supply air temperature to a new reset supply air temperature). All of this, of course, is predicated upon the fact that the reheat air conditioning system which we are considering is a typical one which maintains a constant supply air temperature of 60 degrees, year round, and

Figure 12-1.



REHEAT SAVINGS:

$$\text{AIR } \underline{\text{NOT DELIVERED}}: \text{CFM}_{\text{ND}} \times (72-60) \times 1.08 = \text{BTU}$$

$$\text{AIR DELIVERED: CFM}_{\text{D}} \times (65-60) \times 1.08 = \text{BTU}$$

that, with the way reheat air conditioning systems work, the air supplied to the space is reheated as necessary to maintain the space temperature.

Then, the energy saved in the stream of air not delivered is equal to:

$$\text{cfm}_{\text{nd}} \times (72^\circ - 60^\circ) \times 1.08 = \text{Btu}$$

The logic here is that since we have converted the system to variable air volume, we discovered that we had been supplying more air than was needed to actually cool the space. Now, because we were effectively overcooling this occupied space, the amount of energy that we are saving is the amount of heat that we would have had to put into that extra or excess air to raise it from its supply temperature of 60 degrees up to 72 degrees, at which point, it would no longer be overcooling as it would be delivered at the same temperature as the space.

The heating energy saved on the other stream, the stream of air still being delivered is equal to:

$$\text{cfm}_d \times (65^\circ - 60^\circ) \times 1.08 = \text{Btu}$$

The logic of this is that we have configured the variable air volume system so as to limit its minimum airflow. This is because we don't want to have a situation where cold air "dumps" out of a ceiling diffuser and falls on the head of an occupant in the occupied space. Fortunately, we can keep this total airflow relatively high (say, perhaps, 60% of the original design value) and maintain good air distribution within the occupied space. The problem, however, is that if we arbitrarily set this minimum cfm and it is above the cfm needed to actually cool the occupied space then we will be reheating once again. Therefore, as a further means to save energy, we are assuming in this example that the supply air temperature is being reset upwards during cold weather so as to avoid this overcooling problem and save reheat energy.

Table 12-16. Once again, it is necessary to sum up the individual day cost avoidance values for the month. Table 12-16 does that, albeit with a spreadsheet that looks a little bit silly because we have kept the format of the spreadsheet consistent with the prior spreadsheets. However, in this case we have little information to report, because time of use, other than seasonal time of use, is not an issue with natural gas consumption.

Looking at Table 12-16, we can see that we have a summary for the month of June. In the first data space we have the days of the month, and in the final data space we have the savings in therms and the savings in the cost of therms brought forward from the individual day tabulations.

At this point the reader should note that we do not have any spreadsheets to account for the cooling savings from the variable air volume retrofit. This is because all of the cooling savings will be accounted for through our measurements of post-retrofit energy consumption directly at the chiller. That is to say, the effects of lighting retrofit, the effects of the VAV retrofit, and the effects of the chiller retrofit itself will all be captured at the chiller.

CHILLER RETROFIT USING OPTION B

For the chiller retrofit, utilizing the Option B, we will employ the method CH-B-01, continuous metering. To accomplish this we will do the following:

Table 12-16. VAV Heating Cost Avoidance Summary.

MONTH OF:
COST:
RATE SCH

Jun-98

DAY			DELTA THERMS	DELTA THERMS
1			201	\$188.08
2			202	\$189.02
3			204	\$190.89
4			205	\$191.82
5			203	\$189.95
6			303	\$283.53
7			306	\$286.33
8			205	\$191.82
9			206	\$192.76
10			202	\$189.02
11			205	\$191.82
12			204	\$190.89
13			302	\$282.12
14			305	\$284.93
15			204	\$190.89
16			205	\$191.82
17			202	\$189.02
18			204	\$190.89
19			205	\$191.82
20			308	\$287.74
21			302	\$282.12
22			204	\$190.89
23			202	\$189.02
24			203	\$189.95
25			204	\$190.89
26			202	\$189.02
27			302	\$282.12
28			308	\$287.74
29			204	\$190.89
30			203	\$189.95
31				\$0.00

TOTAL/MAX.

6912 \$6,467.75

- We will measure the existing chiller load versus outside air temperature for a short period of time and extrapolate this data to create an annual load profile. This profile may simply be expressed as a simple linear algorithm relating cooling tonnage to outside air temperature, as will be demonstrated in a small case study discussed a little later in this chapter. This load profile could also be established by computerized building simulation where a small amount of measured data is used to calibrate a building simulation model and then a load profile for a typical weekday and weekend day for each month of the year could be used as the baseline load profile.
- We will install kilowatt-hour transducers and we will measure the post-retrofit energy use of the new chiller(s).
- We will calculate the energy savings by subtracting the post-retrofit energy use from the baseline. Cost avoidance will be calculated by multiplying the kW and kilowatt-hour saved by the appropriate utility rate.
- While they will not be detailed herein, the chiller auxiliaries, such as pumps and a cooling tower, would be handled in the same fashion that the variable frequency drive was handled for the variable air volume retrofit. Alternatively, these could be stipulated and related to chiller energy use, e.g. as a ratio of auxiliary energy use to the chiller energy use.

A Slight (but perhaps helpful) Digression

If you've been reading this entire chapter carefully, at this point some of the material may actually start to become somewhat familiar and perhaps even boring. As a note to readers who are finding themselves bored or a bit confused at this point in the process, more than once during the presentation of this seminar for the Association of Energy Engineers, attendees at the seminar would ask a question like "What is all this spreadsheet stuff? Why can't we just do measurement and verification?" Unfortunately, for these folks, (and yourself, if you find yourself thinking along the same lines) the truth is that this is most likely the way an Option B measurement and verification will be documented. It seems that there are those who imagine that we can just pull off the shelf

some sort of an optical energy meter and point it at the HVAC system and have it “measure” and then print out our energy savings. Again, the problem is manifold. First of all, there is no such instrument, though there are numerous firms such as Architectural Energy Corporation who are laboring hard to create a machine that attempts to do this. However, even their very well developed instrumentation and analysis software requires a multiplicity of sensor interface modules, the temporary installation of numerous sensors and monitoring devices, and, perhaps most critical of all, it requires an astute, experienced HVAC engineer that has the capacity to recognize the type of HVAC system under scrutiny and the data points that need to be monitored. While it seems that there are many that would like to make energy engineers a commodity, the world of mechanical and HVAC engineering is so complex and so varied (very much unlike structural and even electrical systems) that it will never be possible to do away with a seasoned energy engineer. The other problem with all this is that it takes time and costs money and, unless you’re willing to take a year or two to instrument a building beforehand to develop a very, very solid baseline (if you can even then), then the benefit of all this extremely precise instrumentation is questionable. One only needs to read Chapter 7 (Energy Audit Case Studies) to understand how variable the operation of a building can be, and how challenging it can be to determine with some veracity the true baseline conditions. There is a manner of expression that we use in our firm when issues like this come up, and it goes along the lines of “Why use a 1% method to answer a 10% question?”

A lot of foolish thinking abounds, however, as though it is conventional wisdom in the industry. Not long ago, the author attended a seminar put on by the local utility company on the subject of characterizing existing chillers so as to be able to create faithful baseline computerized energy use models of existing buildings and their chilled water systems. After spending a couple of hours presenting instrumentation plans, and statistical methods for analyzing the data (and completely ignoring the fact that an operating engineer spinning the dial on any one of numerous controls can completely invalidate any of the precision measurements being contemplated), I asked a question of the seminar leader. The question was: “So, how long do we need to monitor an existing chiller in order to get enough data in order to be able to properly characterize its performance in a computer simulation?” The seminar leader’s answer was: “At least a year.” Needless to say, everyone in the room who had

ever done a real energy audit on a real project with a real schedule and a real sales force intending to move the project along, realized that most energy auditors are lucky if they get a few weeks or even a few months during which to examine the building. As in some of the other case studies in this book (see Chapter 9), sometimes the amount of time allowed the energy engineers is only a matter of days—if they’re asked to get involved in defining the baseline conditions at all.

So, I apologize to the astute reader for this somewhat tangential discussion. The point of it all is that everyone involved in performance contracting needs to understand that time is limited and our ability to develop baseline knowledge is limited. Therefore, relatively simplistic approaches to developing baselines are the only sensible way to approach a performance contract, and there’s a certain amount of uncertainty that can never be eliminated. It might warrant rereading Chapters 2, 3, and 4 if this is in doubt in the reader’s mind. A solid partnership relationship between the Owner and an ESCo is far, far more valuable than an “iron-clad” contract.

Back to the Chiller Retrofit

Now, finally, we move on to Table 12-17. As we can see, this is a spreadsheet for a specific weekday where we will tabulate the chiller cost avoidance. Astute readers will observe that this spreadsheet is curiously similar to Table 12-10. There are some important differences, however.

In the first data field you’ll note that each of the 24 hours of the day is listed along with the building’s cooling tonnage during each hour of the day. This data, similar to Table 12-10 is from a building simulation, or as we will see later in this chapter possibly some short-term data extrapolated to create an annual energy use algorithm and from that a load profile based on outside air temperature.

In the next data block, we have the baseline or existing data, including the kW/ton for the chiller, its hourly kW/kWh and, applying the rate schedule at the bottom of the spreadsheet, the hourly cost for the kilowatt-hours used to operate the chiller. All of this existing data is typical data developed during the feasibility study. In the next data block, we have the post-retrofit kW/kWh for each hour and, again applying the rate schedule, the kilowatt-hour cost for each hour. In the next data block, we’re able to tabulate the hourly savings in kilowatt-hours, and the hourly avoided cost. At the bottom we can see that the total avoided cost for June 9th, 1998 is \$316.45. As usual, a graph is shown at the

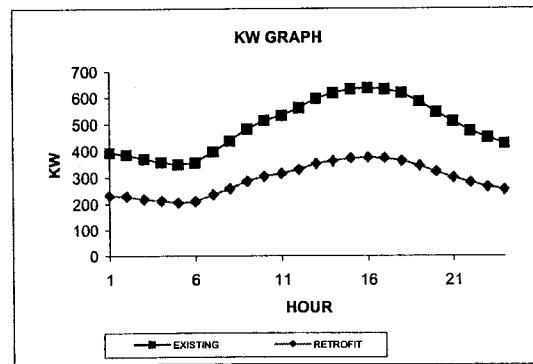
Table 12-17. Chiller Cost Avoidance.

DAY TYPE:			WEEKDAY			DATE:	06/09/98 RATE SCH				
HOUR	TONS:	OSAT	EXISTING			RETROFIT			DELTA	DELTA	
			KW/TON	KW/KWH	KWH		KW/KWH	KWH	KWH	KWH	
1	460	57.5	0.85	391	\$19.78		230	\$11.64	161	\$8.14	
2	452	56.0	0.85	384	\$19.44		226	\$11.43	158	\$8.00	
3	433	55.6	0.85	368	\$18.62		217	\$10.95	152	\$7.67	
4	420	54.6	0.85	357	\$18.06		210	\$10.62	147	\$7.44	
5	408	53.8	0.85	347	\$17.54		204	\$10.32	143	\$7.22	
6	417	54.4	0.85	354	\$17.93		209	\$10.55	146	\$7.38	
7	467	57.9	0.85	397	\$20.08		234	\$11.81	163	\$8.27	
8	515	61.3	0.85	438	\$25.43		258	\$14.96	180	\$10.47	
9	568	65.1	0.85	483	\$28.05		284	\$16.50	199	\$11.55	
10	605	67.6	0.85	514	\$29.88		303	\$17.58	212	\$12.30	
11	628	69.3	0.85	534	\$31.01		314	\$18.24	220	\$12.77	
12	659	71.5	0.85	560	\$32.54		330	\$19.14	231	\$13.40	
13	701	74.5	0.85	596	\$52.27		351	\$30.75	245	\$21.52	
14	724	76.0	0.85	615	\$53.99		362	\$31.76	253	\$22.23	
15	741	77.2	0.85	630	\$55.26		371	\$32.50	259	\$22.75	
16	746	77.6	0.85	634	\$55.63		373	\$32.72	261	\$22.91	
17	741	77.2	0.85	630	\$55.26		371	\$32.50	259	\$22.75	
18	725	76.1	0.85	616	\$54.06		363	\$31.80	254	\$22.26	
19	687	73.4	0.85	584	\$33.93		344	\$19.96	240	\$13.97	
20	641	70.2	0.85	545	\$31.66		321	\$18.62	224	\$13.03	
21	599	67.2	0.85	509	\$29.58		300	\$17.40	210	\$12.18	
22	560	64.5	0.85	476	\$24.08		280	\$14.17	196	\$9.92	
23	530	62.4	0.85	451	\$22.79		265	\$13.41	186	\$9.38	
24	503	60.4	0.85	428	\$21.63		252	\$12.72	176	\$8.91	
TOTAL/AVG.			580	65.9	0.85	11841	\$768.51	6965	\$452.07	4876	\$316.45

(Continued)

Table 12-17.

RATE SCHEDULE: PG&E E19S	EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER
MAX PEAK:	\$13.35	\$0.00
MAX PART PEAK:	\$3.70	\$3.65
MAX DEMAND:	\$2.55	\$2.55
ENERGY CHARGES:		
PEAK:	\$0.08773	\$0.00
PARTIAL-PEAK:	\$0.05810	\$0.06392
OFF-PEAK:	\$0.05059	\$0.05038



bottom to provide data visualization and another error checking opportunity. Just as in all the other Option B daily analysis sheets, no consideration of demand or its cost is given on a daily basis.

Table 12-18. Viewing this table, we can see that it is the monthly summary of chiller cost avoidance, and includes a variety of data just like our other Option B summary spreadsheets. In the first data block is the day of the month with the weekends highlighted. In the next data block, we bring forward from the daily sheets the pre-retrofit kilowatt-hours and kilowatt-hour cost. In the next data block, just like the lighting and the VAV fan energy savings analysis, we bring forward the “peak,” “part-peak,” and “maximum” kW for each individual day, along with the kilowatt-hour and kilowatt-hour cost for the post-retrofit period. In the next data block, the daily difference in kilowatt-hours and kilowatt-hour cost totals are brought forward from the individual day spreadsheets and all of these data blocks have totals and/or maximum values listed at the bottom.

Just as in the prior tables for this option, the pre-retrofit demand data is brought forward, the demand utility rates are applied, and the cost avoidance is calculated in similar fashion.

The graph on this particular spreadsheet is particularly meaningful in that it shows, for example, the reduced cooling load imposed on the plant resulting from reduced fan operation and occupancy on the weekends.

Oh, and did you astute readers notice that this table also has some errors in it? One is identical to that in Table 12-14, while the other is a bit more subtle. A free copy of the book to the first person to identify the other error in this table!

OPTION B VERIFICATION

Verification of Option B methods include:

- Were the proper equipment and systems installed? (The right stuff?)
- Are the systems performing to specification? That is, is the right stuff working correctly and do the systems therefore have the potential to generate the predicted savings?

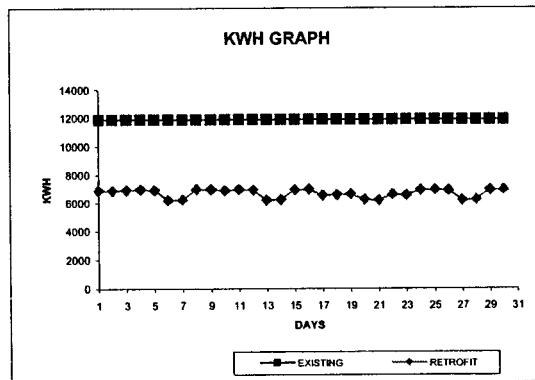
Table 12-18. Monthly Summary of Chiller Cost Avoidance.

PEAK DEMAND FACTOR:	1.0	MONTH OF:				Jun-98		
		COST:		RATE SCH				
DAY	EXISTING-----		RETROFIT-----				DELTA KWH	DELTA KWH
	KWH	KWH	PEAK KW	PART KW	MAX KW	KWH		
1	11849	\$776.51		368	340	368	6872	\$446.01
2	11849	\$776.51		369	341	369	6890	\$447.22
3	11849	\$776.51		371	343	371	6928	\$449.65
4	11849	\$776.51		372	339	372	6946	\$450.86
5	11849	\$776.51		370	342	370	6909	\$448.43
6	11849	\$776.51		332	307	332	6201	\$402.50
7	11849	\$776.51		334	309	334	6235	\$404.68
8	11849	\$776.51		372	339	372	6946	\$450.86
9	11849	\$776.51		373	344	373	6965	\$452.07
10	11849	\$776.51		369	341	369	6890	\$447.22
11	11849	\$776.51		372	339	372	6946	\$450.86
12	11849	\$776.51		371	343	371	6928	\$449.65
13	11849	\$776.51		331	306	331	6184	\$401.41
14	11849	\$776.51		333	308	333	6218	\$403.59
15	11849	\$776.51		371	343	371	6928	\$449.65
16	11849	\$776.51		372	339	372	6946	\$450.86
17	11849	\$776.51		350	341	350	6542	\$424.62
18	11849	\$776.51		352	343	352	6579	\$427.04
19	11849	\$776.51		353	339	353	6598	\$428.25
20	11849	\$776.51		335	305	335	6252	\$405.77
21	11849	\$776.51		331	306	331	6184	\$401.41
22	11849	\$776.51		352	343	352	6579	\$427.04
23	11849	\$776.51		350	341	350	6542	\$424.62

Table 12-18.

24	11849	\$776.51	370	342	370	6909	\$448.43	4940	\$328.08	
25	11849	\$776.51	371	343	371	6928	\$449.65	4921	\$326.86	
26	11849	\$776.51	369	341	369	6890	\$447.22	4959	\$329.29	
27	11849	\$776.51	331	306	331	6184	\$401.41	5665	\$375.10	
28	11849	\$776.51	335	305	335	6252	\$405.77	5597	\$370.74	
29	11849	\$776.51	371	343	371	6928	\$449.65	4921	\$326.86	
30	11849	\$776.51	370	342	370	6909	\$448.43	4940	\$328.08	
31							\$0.00		\$0.00	
TOTAL/MAX.		355470	\$ 23,295.30	373	344	373	200210	\$12,994.83	155260	\$10,300.47
PEAK DEM.	634	\$ 8,463.90				373	\$4,979.55		\$3,484.35	
PART PEAK	584	\$ 2,160.80				344	\$1,272.80		\$888.00	
MAX DEM	634	\$ 1,616.70				373	\$ 951.15		\$665.55	
TOTAL COST AVOIDANCE:									\$15,338.37	

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER	
MAX PEAK:	\$13.35	\$0.00	
MAX PART PEAK:	\$3.70	\$3.65	
MAX DEMAND:	\$2.55	\$2.55	
ENERGY CHARGES:			
PEAK:	\$0.08773	\$0.00	
PARTIAL-PEAK:	\$0.05810	\$0.06392	
OFF-PEAK:	\$0.05059	\$0.05038	



- Finally, the question “Does the equipment continue to operate and perform through the term of the contract?” must be answered.

OPTION B ISSUES

Those using Option B should remember that:

- Energy savings determined using Option B are based on measured performance and measured operation
- Option B will always involve specialized end-use metering and subsequent data analysis. In fact, this data analysis can be significant, to the point of being overwhelming.
- This option will capture interaction where multiple retrofits are implemented. For example, the lighting savings effect on the building cooling load will be reflected in measurements taken at the chiller.
- Option B tells you about both performance and operation of the project over the term of the contract.
- Finally, Option B can be very expensive due to the fact that it requires a significant amount of metering and instrumentation to be installed and an awful lot of data reduction and analysis. The latter has the potential to significantly outweigh the cost of the hardware installation, especially when considered over the term of the contract.

OPTION C WHOLE FACILITY MEASUREMENT

Option C is perhaps the oldest methodology in use for measurement and verification. In fact, it was the first methodology used when the industry was in its infancy in the late 1970s and early 1980s. In its original, historical use, it was referred to as utility bill comparison because the measured energy use data which was commonly available at that time was simply the data available from the utility company meters, both gas and electric, that were already installed in the buildings being retrofitted.

This approach is appropriate for projects where whole-building

analysis is desired, say to capture the interactions and effects of non-measurable retrofits (such as window replacement), or where this approach is thought to be sufficient for reasonably accurate verification of the retrofit's savings.

This option requires either utility bill data or whole building measured data, say on a college campus where individual buildings submeters are installed.

This method is also strongly influenced by statistical approaches such as normalizing the data to other independent variables, generally by means of using regression models.

Using Option C, the savings are determined by comparing the post-retrofit energy use to the baseline, when the baseline has been projected into the future based on the regression model developed for the facility.

Commercially available software is typically used to implement this methodology, including three fairly popular programs called Faser, Metrix, and Utility Manager.

A contributing author has blessed us with a fairly extensive discussion of the use of "canned" software for Option C M&V in Chapter 14. While his discussion is exemplified in only one of the programs available, the vast majority of his discussion is germane to the subject of Option C M&V in general, as all the programs attempt to do pretty much the same thing.

Adjustments

Option C frequently provides for adjustments in the measured energy savings for changes in the building occupancy, whether building square footage, added or removed loads, and independent process variables (say, in a manufacturing facility, the units of production).

This methodology will require tracking the various variables throughout the term of the contract, and, for example requires the pro-rating of the utility data to match the independent variables such as weather. This is because facilities frequently have multiple utility meters, which are seldom read on the exact same day. In addition, the process or independent variables (whether units of production) are frequently tracked on a calendar month basis, whereas the utility data is almost never on a calendar month basis. Figure 12-2 is provided to the reader as a glimpse into the number of possible types of linear regression models that can be created for a facility. This book will not attempt to educate the readers on the subject of regression models, but may offer some small

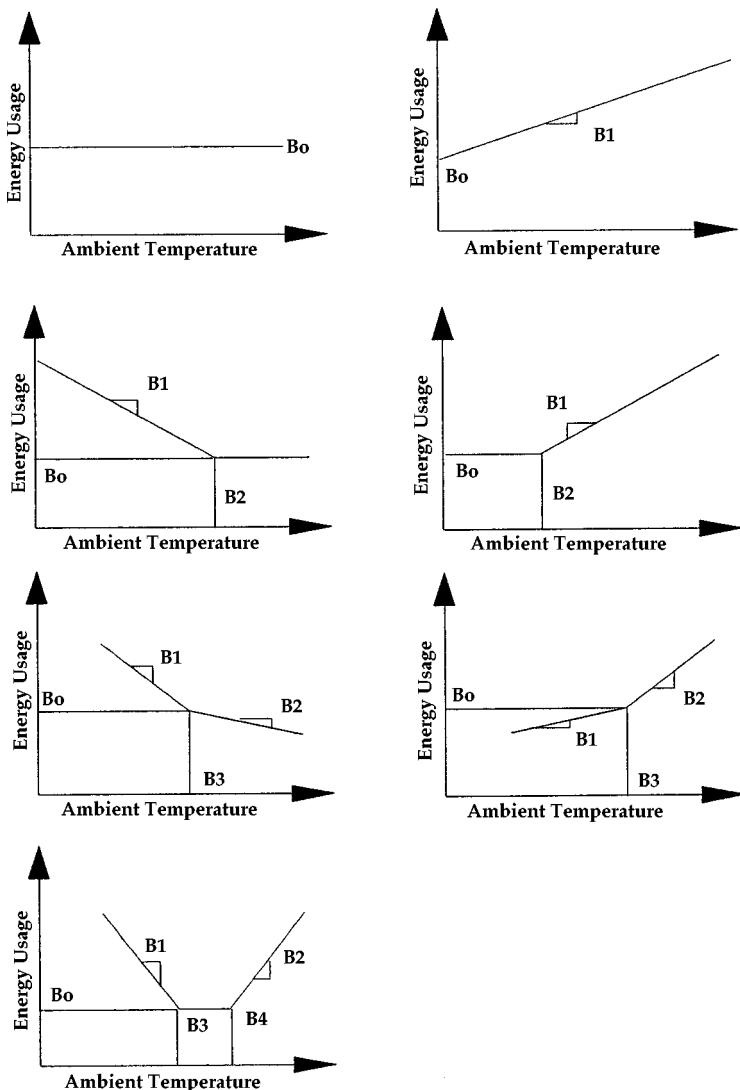
insight into how and where they might be effectively used. Readers are referred to the references in the appendix for more detailed information about linear regression models.

In addition, readers unfamiliar with this methodology and the programs available to employ it are referred to the California Energy Commission document entitled "Energy Accounting," which is also listed in the references.

Some important considerations that readers should keep in mind when considering the use of Option C include the following:

- Do you know, or is it possible to identify, those independent variables that influence the building's energy use? In one building we worked on, a new chief engineer took over the operation of the facility and operated the building heating systems in such a conservative fashion that the building's natural gas consumption doubled from the prior year. (The performance contractor working on this building was not aware of this factor and was unable to successfully prepare a regression model of the building's heating energy use as a result.)
- Has the energy use in the facility been relatively stable, and is the program of retrofit anticipated to change the building's energy use such that this change will not be masked or concealed by the normal fluctuations in energy use in the facility?
- Instead of having a third party more or less blindly perform linear regression analysis, it is a good idea to document the various end uses of energy in the facility according to the type of energy that they consume. For example, a building might use electricity for cooling and natural gas for heating, but it could use electricity for both heating and cooling, or it could use natural gas for both heating and cooling as well. This sort of documentation will serve as an assist should a third party be involved in doing the linear regression modeling.
- Adjustments to the measurement and verification accounting of energy savings results, for factors like changes in building occupancy, square footage, or added or reduced loads, cannot generally be modeled using regression analysis, since there typically is no data for past changes in these variables. Such changes require engineering analysis, either by means of manual calculations or, even

Figure 12-2.



better yet, by means of building simulation analysis. A well-documented, investment-grade audit employing computerized building simulation during the project planning phase can be extremely valuable here in providing a foundation for future negotiation of the effects of changes of this sort.

The whole idea, of course, of the regression model is to allow for adjustments in retrofit savings figures as a result of changes in variables (such as weather) which are beyond the control of either party to the contract. The basic assumption is that the energy saved is equal to the pre-retrofit consumption less the post-retrofit consumption. A problem exists if, for example, the weather in a particular month is extremely inclement compared to the weather during the baseline period. Such inclement weather could cause the building to use more energy, and would make the actual savings appear to be less than they should be. By taking the baseline energy use and correcting it for changes in independent variables like weather, a new “projected baseline” can be established, against which the post-retrofit energy consumption might be fairly compared. Recognizing that weather does not change very much on an annual basis, and realizing that variables such as weather may actually have a relatively small impact on a building’s energy use (particularly larger, more complex buildings), correction for these variables for a multi-year contract may actually be ignored as long as these factors are understood, and as long as both parties understand that the resulting documentation of energy savings may fluctuate somewhat on a month-to-month or even a year-to-year basis, and that it will all balance out in the long run.

OPTION C VERIFICATION

Similar to Options A and B, Option C verification includes the following:

- It is important on a periodic basis to verify that the proper equipment and systems were installed (the right stuff).
- Next, the systems should be examined to verify that they are performing according to their specifications, i.e., is the right stuff working correctly and do the systems have the potential to generate savings?
- Finally, all of the above are reviewed periodically to verify that the systems continue to operate and perform as expected to when installed.

OPTION C ISSUES

The following issues need to be considered when selecting Option C:

- All of the instrumentation (metering) is often already in place in the form of a utility company meter.
- This option tends to be less expensive due to the reduced costs of instrumentation and the reduced cost of data handling, particularly because off-the-shelf software is commercially available.
- Seeing the results in the utility bill will generally tend to increase confidence in the results, but does not necessarily mean that the retrofit project succeeded. The public at large (and building owners specifically) are very used to seeing the utility bills, and a system of measurement and verification based on this common and familiar data carries (deserved or not) significant credence.
- Option C captures all interactive effects (good or bad) since our measurement “envelope” encompasses the entire facility.
- Again, the issue of being able to determine the independent variables is critically important.
- If there is a lot of “noise” in the utility consumption data, the effects of the retrofit project may be concealed by these normal variances in the utility consumption data.

OPTION D CALIBRATED SIMULATION

This option was introduced in the release of the International Performance, Measurement, and Verification Protocol in December 1997. While it is identified as an entirely separate option under the protocol, computerized simulation frequently is, and generally should be, an integral part of any rigorously performed project and is potentially an integral part of Options A, B, and C as well.

Option D employs the use of a calibrated building simulation to demonstrate the “before” and “after” retrofit energy use of the facility. Subtracting the difference between these two calibrated simulations produces the energy savings produced by the project. This methodology requires the use of “hourly” building simulation tools such as Trace, DOE-2, and similar programs.

The calibration of the simulation models is done for both the pre- and post-retrofit models by calibrating them to specific end-use and whole-building energy use data. For example, in a new building, it is possible to go into the building after it is constructed and directly measure the lighting fixture energy use. Now, it may be that the total number of fixtures installed in the building once it is actually constructed and occupied may be somewhat different than the number of fixtures originally anticipated during the design phase. Simulating the existing building with its high efficiency lighting systems calibrated to the actual measured lighting energy use, and comparing this to an updated baseline computer model that had been calibrated to show up the correct number of fixtures finally installed, will give a faithful estimate of the energy to be saved by installing more efficient lighting fixtures, and will also capture interactive effects, such as reduced air-conditioning energy consumption. Just as this example implies, the one area in which Option D is likely to be the optimum choice is in the case of a new facility where there is no existing building to survey, but the building owner would benefit from having a third party performance contractor enhance the building's construction by investing in more efficient infrastructure systems such as lighting, HVAC, and controls. By using Option D, these parties can agree to a reasonable methodology for establishing with a relatively high degree of certainty the actual energy savings achieved by the increased investment in building infrastructure.

As a final comment on Option D, it should be realized that Option D requires special skill in the field of computerized building simulation (as discussed in the ASHRAE symposium paper shown in the bibliography). However, this methodology may result in no added costs for measurement and verification if a rigorous calibrated building simulation is part of the feasibility study process in the first place.

HOW MUCH CAN YOU DO WITH VERY LITTLE?

As we are concluding the chapter on project-specific examples, it seems appropriate to share with the readers some details of a particular project which we believe shows that a fairly high degree of confidence in a projection of energy savings and the resulting measurement and verification can be achieved with relatively little instrumentation and a relatively modest engineering labor effort.

The project in question is a high-tech research and manufacturing facility in the Silicon Valley area of Northern California. This particular owner was interested in upgrading their central cooling plant and adding thermal energy storage so as to both improve the overall reliability of the plant and reduce its cost of operation.

In order to quantify the building's existing chiller plant energy use, a very simplistic approach was developed that included the following:

- Monitoring of the chiller plant only by means of recording amperage for a single leg of each chiller's power supply. This was done with an AEC Microdata logger employing a 3000 Amp clamp-on current transformer, one logger/CT set used for each of the two chillers in the plant.
- Monitoring of ambient temperatures during the roughly two weeks of current monitoring.
- Use of a mathematical algorithm to convert chiller amps to tons of cooling.
- Preparation of a histogram (also known as a "scatter diagram").
- Modeling of the facility's annual load profile using a computer simulation employing a linear ambient temperature vs. tons algorithm.
- Modeling of the retrofit plant employing the Electric Power Research Institute's (EPRI) "Cool Aid" computer simulation program.

Figures 12-3 and 12-4 show the formulas that were used to convert the field measured amperage data into equivalent tons of cooling capacity for the two chillers that were monitored. These figures are rather complicated, and we will not attempt at this point in the book to explain them in every detail. However, readers who are interested may review the technical bulletin in the Appendix or print out the technical bulletin from ERA's website at www.eraenergy.com. We will attempt to provide a thumbnail sketch of what is going with these figures at this point in the chapter.

In our experience observing chillers in the field, we have learned that it is exceedingly challenging to perform a good direct measurement of tonnage using field instrumentation. Differential temperatures are not difficult to achieve but getting a good handle on flow rates can be very time consuming and at times elusive. Recognizing the

Figure 12-3. Calculation of Chiller Tonnage Based on % FLA.

DATE: 09/23/07		INIT: HK		DATA FOR ACTUAL CHILLER										-%FLA MODEL		-%TONS MODEL	
--MOTOR DATA--		---CHILLER DATA---		CHILLER % KW VS. % LOAD		CHILLER CAPACITY = 535.00 TONS		SEE FORMULA BELOW		SEE FORMULA BELOW							
POWER FACTOR VS. % LOAD FROM TYPICAL MOTOR DATA		FROM TYPICAL CONSTANT		CHILLER KW/TON = 0.77													
EXPOENT = 2.85		SPEED CENTRIFUGAL CHILLERS		TONS		KW		ACTUAL TEST DATA		TEST GRAPH		EXPOENT: 2.00		WEIGHTED		WEIGHTED	
		CONV % NOMINAL		@		POWER		% FLA		TEST GRAPH		MODEL		WEIGHTED		MODEL	
% KW	P.F.	% TONS	UNIT % KW	KW/TON	% TONS	% KW	POWER	AMPS	AMPS	% KW	P.F.	% FLA	% ERROR	% TONS	% ERROR		
5	0.26	5	25	500	27	103	0.60	207	40	5	-	40	0.1%	0	-5.0%		
10	0.36	10	26	260	54	107	0.61	211	40	10	-	41	0.0%	9	-1.5%		
15	0.45	15	28	187	80	115	0.64	218	42	15	-	41	-0.2%	17	2.3%		
20	0.53	20	30	150	107	124	0.66	225	43	20	-	42	-0.3%	23	2.9%		
25	0.60	25	33	130	134	134	0.69	234	45	25	-	44	-0.6%	28	3.3%		
30	0.66	30	35	117	161	144	0.72	242	46	30	-	45	-0.7%	33	2.8%		
35	0.72	35	38	109	187	157	0.75	253	48	35	-	47	-0.8%	38	2.5%		
40	0.76	40	42	105	214	173	0.78	267	51	40	0.79	50	-1.2%	43	3.0%		
45	0.80	45	46	102	241	189	0.81	281	54	45	-	52	-1.4%	48	3.0%		
50	0.84	50	50	100	268	206	0.84	295	57	50	-	55	-1.4%	53	2.6%		
55	0.87	55	54	98	294	222	0.86	310	59	55	0.85	58	-1.2%	57	2.0%		
60	0.89	60	58	97	321	239	0.88	326	62	60	-	62	-0.8%	61	1.2%		
65	0.91	65	63	97	348	260	0.90	346	66	65	-	65	-0.9%	66	1.2%		
70	0.92	70	68	97	375	280	0.92	367	70	70	-	69	-0.9%	71	1.1%		
75	0.93	75	74	99	401	305	0.93	393	75	75	-	74	-1.6%	77	1.8%		
80	0.94	80	79	99	428	325	0.94	416	80	80	-	78	-1.4%	81	1.4%		
85	0.95	85	84	99	455	346	0.95	440	84	85	-	83	-1.0%	86	1.0%		
90	0.95	90	90	100	482	371	0.95	470	90	90	-	89	-1.5%	91	1.4%		
95	0.95	95	95	100	508	391	0.95	496	95	95	-	94	-0.9%	96	0.8%		
100	0.95	100	100	100	535	412	0.95	522	100	100	-	100	0.0%	100	0.0%		
												Avg Error:	Avg Error		Avg Error		
												-0.8%	Avg Error		1.4%		

$$\text{FORMULAS: } \% \text{FLA} = (0.4 + ((\% \text{TONS}/100)^{\text{EXPOENT}} * 0.6)) * 100$$

$$\% \text{TONS} = 100 * (((\% \text{FLA}/100) - 0.4) / 0.6)^{1/\text{EXPOENT}}$$

NOTE: %FLA/100-.04 MUST BE A POSITIVE NUMBER

(Continued)

Figure 12-3.

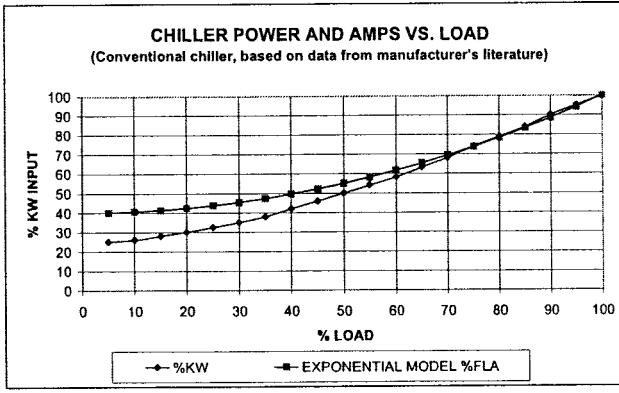
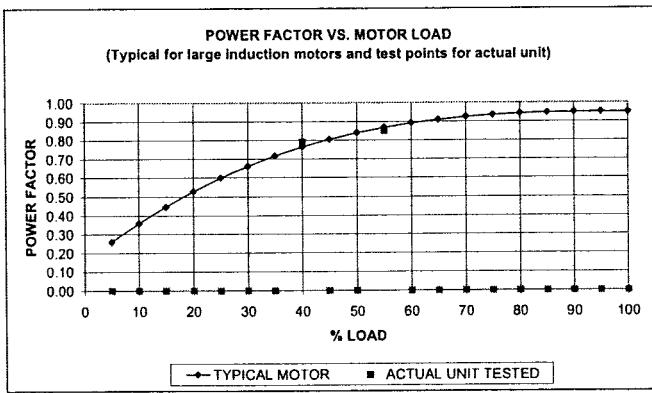


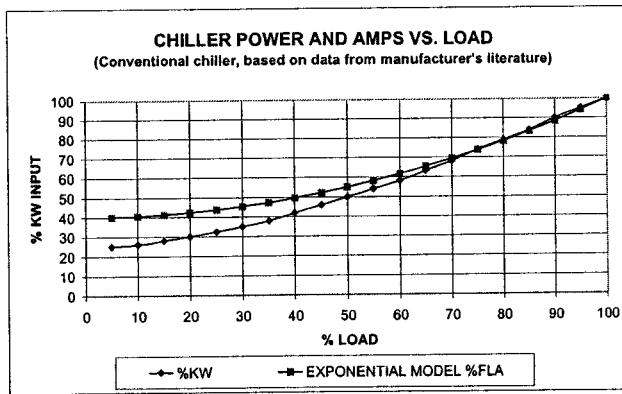
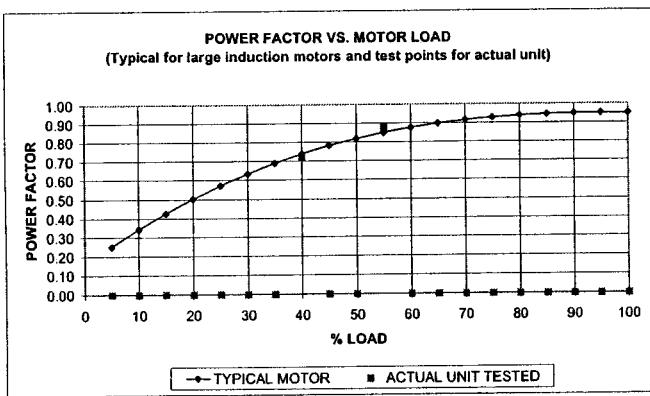
Figure 12-4. Calculation of Chiller Tonnage Based on % FLA

FORMULAS: **%FLA =** $(0.4 + (((\%TONS/100)^EXPOENT)*0.6)) * 100$
% TONS = $100 * ((((\%FLA/100)-0.4)/0.6)^1/EXPOENT)$

NOTE: %FLA/100-04 MUST BE A POSITIVE NUMBER

(Continued)

Figure 12-4.



challenging nature of direct measurement of instantaneous tons, and realizing that there is generally precious little time available in the field and in the overall engineering budget, we began to look for a quicker and easier way to get a pretty good handle on the tons being produced by chillers.

After we thought about it for a while, we realized that we commonly used a current transformer on at least one of the legs of the power feed to each chiller. Further, we realized that it would be a simple matter in the field to place a clamp-on current transformer adjacent to the existing permanently installed current transformer which is part of the chiller's built-in instrumentation. We also realized that we knew a lot about the performance of chillers with respect to their kW/ton at different load values, and we knew a lot about the power factor of large motors at varying loads, as there is a fair amount of literature on these subjects. Putting all of these ideas together, we started to play around with a way that we could mathematically relate chiller amps to tons being produced by the chiller. One caveat here is that the plant in question had a constant condenser water temperature. In a plant with condenser water reset, there would have been yet another variable to throw into the calculation mix.

So, in the figure, you will see a graph that shows typical power factor at percent load for large induction motors. You will also notice on this graph that there are two data points plotted for the actual chillers that were measured in the field. This was done as a simple spot check to make sure that we were not far afield in our assumed relationships between the various parameters. Looking at the graph in the lower left-hand corner in both of the figures, it can be seen that the data points lie very close to the assumed characteristic curve. In the other graph we see typical data from manufacturer's literature showing the percent kW input versus percent load. For most centrifugal chillers the kW/ton at full load is the chiller's nominal kW/ton. Constant speed machines tend to run a little more efficiently below the full load point until they get down to about 40% load, at which point the parasitic losses such as friction, and the fact that we are making the impeller work against nearly closed inlet vanes, means that our efficiency goes down. And as can be seen from the curve, at 5% load we are at about 25% kW input. In other words, about 500% of the chiller's nominal kW/ton!

While the Ph.D.'s could probably do this part of the test better

than we did, we started playing around with formulas which would calculate full load amps from tons, and would “back” calculate tons from percent full load amps. Both of these formulas are shown in the figure. As can be seen in the upper right hand corner of the figures, these formulas are tested at various percent loads to see how their results correspond to typical chiller data. As can be seen from the columns of figures, the percent error (of our mathematical “model” versus typical actual performance data) is rather modest throughout the range of possible measurements.

So, as detailed in the Appendix, we have a mathematical means of translating, with a reasonably high degree of confidence, a simple chiller amperage measurement into the tons that the chiller is delivering. Armed with this tool, we were able to take the amperage data that was measured over a short time interval and convert it into tons. A histogram of this data is shown in Figure 12-5. This histogram is also shown with the best-fit linear regression line plotted through the data. For this particular assignment, we chose to do a simple linear regression analysis, and the results of that analysis are shown in Table 12-19. This is all work, by the way, that is simply done in Microsoft Excel, using the existing functions that are already available in that spreadsheet program. “R square” is the coefficient of correlation and generally gives you an idea of how well the linear regression formula matches the actual data. An “R square” of .76 is not bad. Now, once again, the Ph.D.’s could do perhaps even more with this than we did, say by using an exponential function instead of linear (there does appear to be a slight downward-facing concavity to the data), but for our practical purposes, this seemed to work pretty well (and we got a pretty good R square value). Furthermore, there is in all likelihood, a multiplicity of other factors which we did not have time to investigate, such as production runs or R & D testing activities which could have been used to model the actual data with more precision than just using ambient temperature.

Furthermore, it turns out that there is additional support in the field of HVAC for using a linear model. As can be seen in Figure 12-6, one way of thinking about a building and its heating and cooling loads, is to consider its equilibrium or balance temperature. Heat gain (requiring air conditioning) is shown above the zero line, and heat loss (requiring heating) is shown below the zero line. If we were to consider a simple building which was being maintained at 75 degrees,

Figure 12-5.

Tons vs. OSA Temp

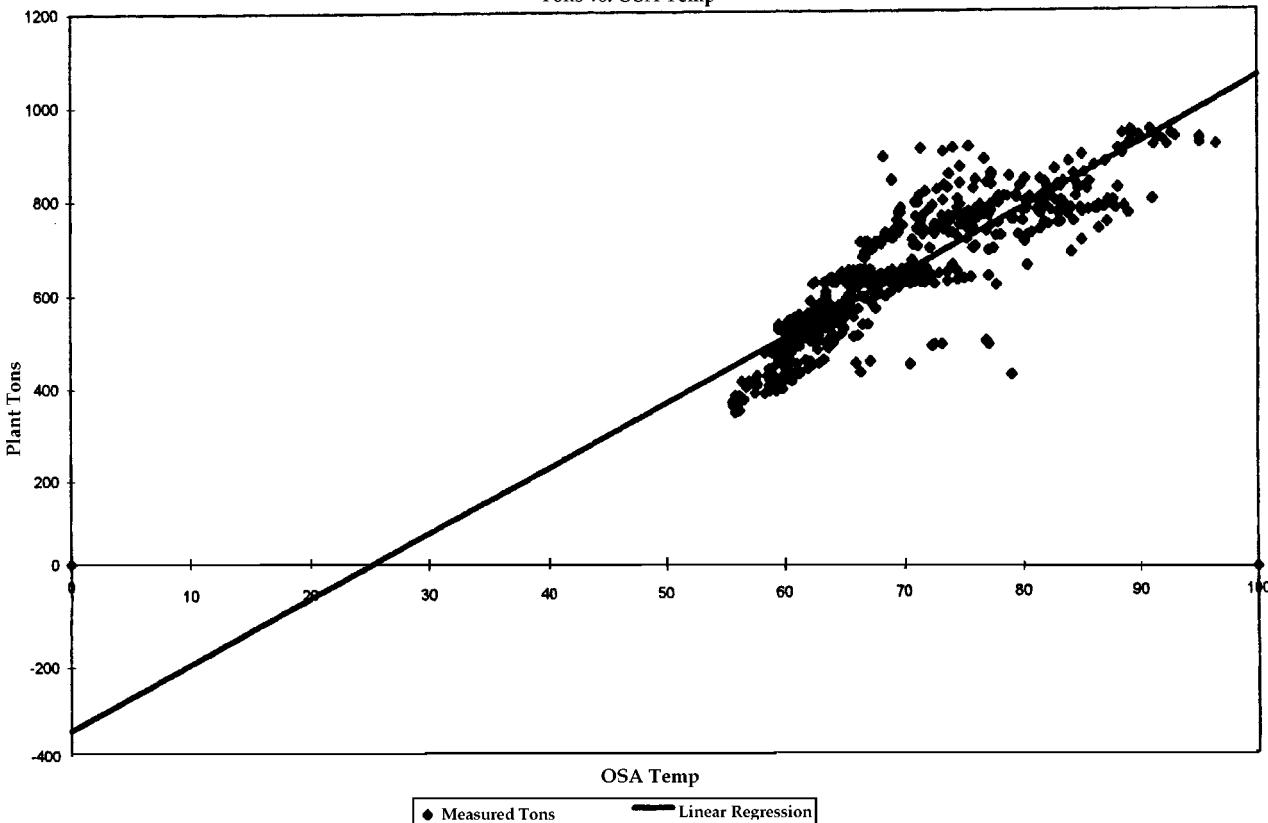
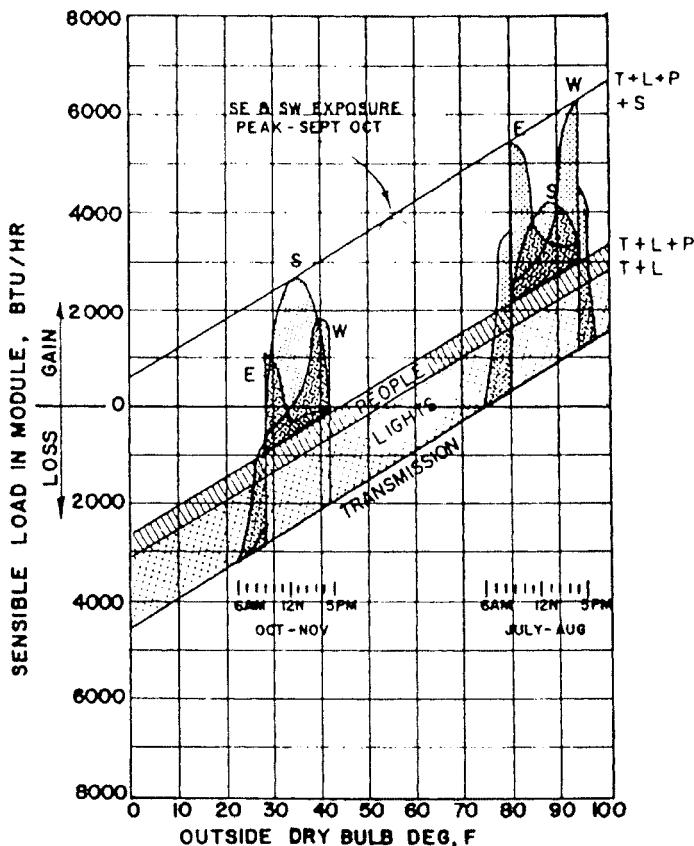


Table 12-19.

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.876663033							
R Square	0.768538074							
Adjusted R Square	0.76818143							
Standard Error	66.77988798							
Observations	651							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	1	9609966.954	9609966.95	2154.916873	2.1195E-208			
Residual	649	2894250.182	4459.55344					
Total	650	12504217.14						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.000%	Upper 95.000%
Intercept	-335.8524904	21.04296179	-15.9603241	1.28082E-48	-377.1730045	-294.5319762	-377.1730045	-294.5319762
X Variable 1	13.94717684	0.300449196	46.4210822	2.1195E-208	13.35720688	14.5371468	13.35720688	14.5371468

Figure 12-6.



had no internal heat gains or losses, was uninfluenced by the sun, and was only influenced by the ambient temperature, we would have a net gain at an ambient temperature above 75 degrees and a net loss at an ambient temperature below 75 degrees. If we make the building a little more complicated, and add heat gain from lights in addition to that from transmission, we can see that the balance point for the building now moves to the left, or a lower ambient temperature since there's heat inside the building to offset transmission losses through the envelope of the building. As can be seen in the figure, this temperature is about 53 degrees. Taking it a step yet further, and adding occupants to the space, this raises the internal heat gain and moves the balance temperature even lower. Finally, adding solar effects takes

the analysis one step further. The interesting thing is that if you consider a building in total, i.e., considering all of its exposures simultaneously and, assuming that most buildings are generally occupied only during daylight hours, we can see that assuming a linear relationship between ambient temperature and a building's total cooling needs is a fairly rational assumption, and that to find a more precise relationship, one would have to do an hour-by-hour analysis of all the influences on a building. But of course, that's what we're all about here—trying to find shortcuts to come up with reasonably accurate answers, in contrast to just guessing (which is all too often what is actually employed).

Now, it just so happens that in the mid-1980's, ERA developed (and still sells) a building simulation spreadsheet (called **©BEST**, or the *Building Energy Simulation Template*) with some interesting features. It takes a near sinusoidal model for typical monthly diurnal temperature cycles, combined with average maximum and average minimum monthly ambient temperatures, to produce a typical monthly 24-hour temperature profile for each month of the year. It then employs a linear load-versus-temperature algorithm (as shown in Figure 12-7) to predict the hourly cooling and heating loads on a building. While this spreadsheet simulation tool is exceedingly simple, it had been demonstrated to be quite efficacious in its use (as documented in ASHRAE Symposium Paper AN-92 listed in the bibliography). As can be seen in Table 12-20, this algorithm is easily defined in

Figure 12-7. Load vs. Temperature Algorithm.

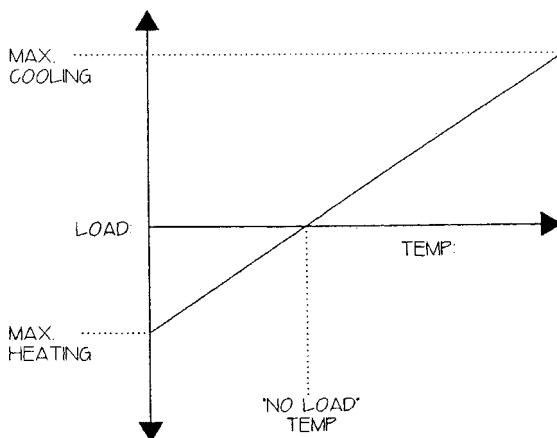


Table 12-20.

TITLE: XICOR/TE_SDV	HEATING NO-LOAD TEMPERATURE:	75
	COOLING NO-LOAD TEMPERATURE:	25
VARIABLE:	HEATING:	COOLING:
LENGTH OF SEASON (1-12):	0	12
START MONTH (1-12):	1	1
HVAC SYSTEM OPERATION:		
DAY TYPE #1 HOURS PER DAY (1-24):	11	24
DAY TYPE #1 START HOUR (1-24):	8	7
DAY TYPE #1 LOAD MULTIPLIER:	1	1
DAY TYPE #2 HOURS PER DAY (1-24):	8	24
DAY TYPE #2 START HOUR (1-24):	9	7
DAY TYPE #2 LOAD MULTIPLIER:	0.7	1
DAY TYPE #3 HOURS PER DAY (1-24):	0	24
DAY TYPE #3 START HOUR (1-24):	1	7
DAY TYPE #3 LOAD MULTIPLIER:	1	1

-----"PAGE DOWN" FOR NEXT PAGE-----

HEATING AND COOLING ENERGY USE VARIABLES

VARIABLE:	HEATING:	COOLING:
FUNCTIONAL ENERGY USE (1-10):	2	4
TYPE OF ENERGY USED (1-3):	2	3
UNITS:	GAS THRH	TON-HRS
PEAK HOURLY LOAD:	0	790
MINIMUM LOAD(not weather related):	0	0
DAY TYPE #1 MINIMUM LOAD MULTIPLIER:	1	1
DAY TYPE #2 MINIMUM LOAD MULTIPLIER:	1	1
DAY TYPE #3 MINIMUM LOAD MULTIPLIER:	1	1
HIGH AMBIENT TEMP. LOCK-OUT:	100	100
LOW AMBIENT TEMP. LOCK-OUT:	0	0

ELECTRICAL DEMAND ANALYSIS VARIABLES

	SUGGESTED KW GRAPH	
ENERGY TYPE FOR ELECTRICITY (1-3):	1	MAX VALUE: 1300
PEAK DEMAND MONTH (6,7,8 or 9):	7	USE:
MEDIAN DEMAND MONTH (4,5,10 or 11):	4	1300

the simulation spreadsheet input by indicating the peak cooling tons at the maximum temperature in the temperature data (remembering that the temperature data is average data) and defining a no-load temperature at which the cooling load is zero. These two points define a straight line which the program then can utilize, combined with actual weather data from the locale of the project to predict a typical monthly load profile for an entire year. This process produced the data shown in Table 12-21.

Since the project in question was subject to a utility company rebate, it was necessary to employ a thermal energy storage evaluation tool that was approved and accepted by the utility. In this case, it was the Electric Power Research Institute's Cool Aid program which was required for the analysis. The results of this analysis are shown in graphic form in Figure 12-8. The program provides an interesting graphical output where the cooling load is shown as a shaded background and the amount of cooling in the storage system is shown by a continuous line. The amount of cooling produced by the cooling system, which is used to support the cooling load directly (see hours 7 through 12), supplement the TES (see hours 13 through 18) and to simultaneously charge the TES and support the cooling load (see hours 19 through 6) are indicated by the "to charge" bars in the graph. As can be seen from the graphs, the cooling supply from one of the two chillers is shut down from noon to six and the cooling available in the storage system is used to satisfy the load with the other chiller running at essentially full capacity, with the result that the tank is essentially depleted at the end of the noon to six period (and is re-charged from hour 19 to hour 6 the following morning).

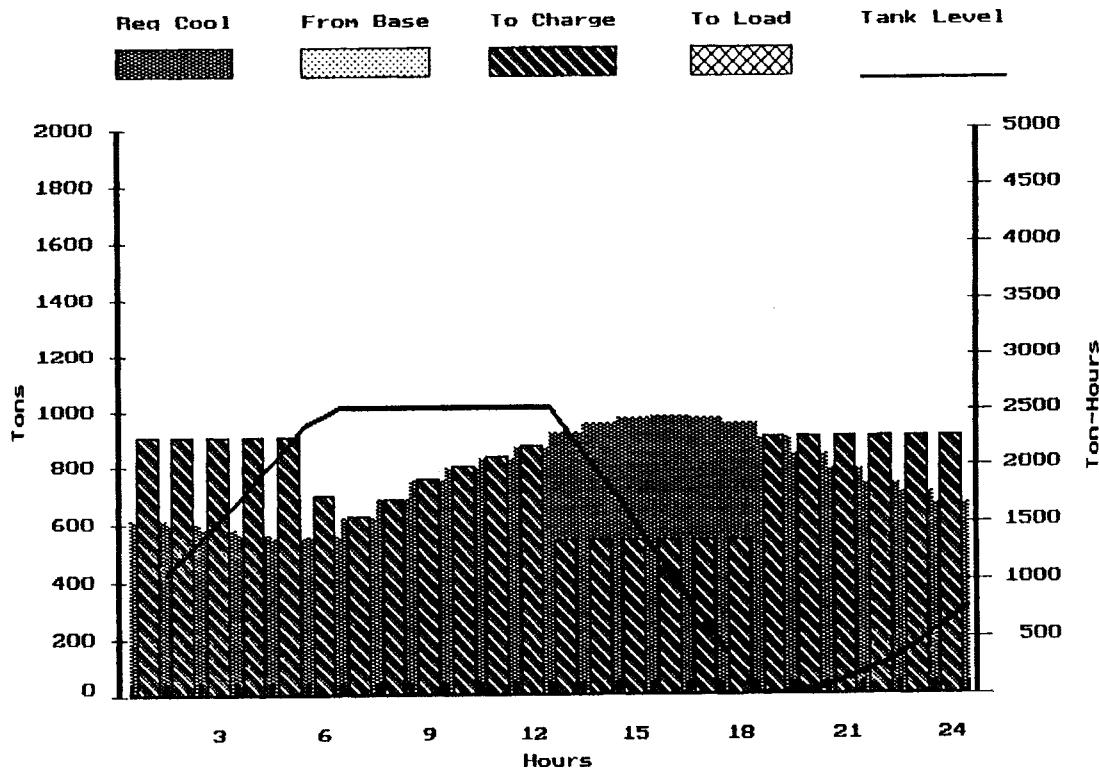
It is important to make a distinction here which is perhaps not always clearly understood. When it comes to energy use and the cost of the commodity (e.g., kWh), average conditions and average weather data are most important. This is because we are attempting to take the past and project it into the future and it is the typical days which we experience most often, not the extreme days. However, for machinery like air conditioning, when it comes to demand charges, the machinery is required to perform on the worst day or month of the year, and we pay for the installed costs on that basis and for electrical demand on that same basis (i.e., the worst case condition), even though it does not persist for a very long period of time.

The bottom line in this discussion of how much can be done

Table 12-21.

TITLE: XICOR/TES_SDY	SYS	WEEKDAY COOLING LOAD PROFILES AND HOURLY TEMPERATURES																																															
		ON? 1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21		22		23		Avg Load	TON-HRS PER MO.
		0/1	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12									
JANUARY																																																	
HOURLY TEMPERATURES:		45.0	44.6	43.8	43.2	42.7	43.1	45.2	47.3	49.7	51.2	52.3	53.6	55.5	56.4	57.2	57.4	57.2	56.5	54.8	52.8	51.0	49.3	48.0	46.8																								
HOURLY LOADS:	1	283	278	266	258	251	256	287	317	350	372	387	406	432	446	456	460	456	447	423	394	368	345	326	309	357										180059													
FEBRUARY																																																	
HOURLY TEMPERATURES:	1	46.4	45.9	45.0	44.3	43.7	44.1	46.7	49.2	51.9	53.8	55.0	56.6	58.7	59.9	60.7	61.0	60.7	59.9	58.0	55.6	53.4	51.5	49.9	48.5										187310														
HOURLY LOADS:	1	303	297	283	273	265	272	308	343	382	408	425	448	478	494	507	511	507	495	467	434	403	375	354	334	390										232823													
MARCH																																																	
HOURLY TEMPERATURES:	1	47.7	47.2	46.1	45.3	44.6	45.1	48.0	50.9	54.0	56.2	57.6	59.4	61.9	63.2	64.2	64.5	64.2	63.3	61.0	58.3	55.8	53.5	51.8	50.2										227053														
HOURLY LOADS:	1	321	314	299	287	278	285	327	367	412	442	462	488	523	542	556	560	556	543	511	472	437	405	380	357	422										276012													
APRIL																																																	
HOURLY TEMPERATURES:	1	50.8	50.2	49.1	48.2	47.5	48.1	51.2	54.2	57.6	59.9	61.4	63.3	66.0	67.4	68.5	68.8	68.5	67.5	65.1	62.2	59.5	57.1	55.2	53.4										306475														
HOURLY LOADS:	1	366	358	341	329	319	327	371	415	462	495	516	544	581	601	617	621	617	602	568	527	489	455	428	403	473										296713													
MAY																																																	
HOURLY TEMPERATURES:	1	54.1	53.5	52.3	51.4	50.7	51.3	54.5	57.6	61.1	63.4	65.0	67.0	69.7	71.2	72.3	72.6	72.3	71.2	68.7	65.8	63.0	60.5	58.6	56.8										231202														
HOURLY LOADS:	1	412	405	387	375	365	373	418	463	512	545	567	595	634	655	670	675	670	656	620	578	539	504	476	451	523										285012													
JUNE																																																	
HOURLY TEMPERATURES:	1	57.5	56.9	55.6	54.6	53.8	54.4	57.9	61.3	65.1	67.6	69.3	71.5	74.5	76.0	77.2	77.6	77.2	76.1	73.4	70.2	67.2	64.5	62.4	60.4										336508														
HOURLY LOADS:	1	460	452	433	420	408	417	467	515	568	605	628	659	701	724	741	746	741	725	687	641	599	560	530	503	580										211999													
JULY																																																	
HOURLY TEMPERATURES:	1	59.8	59.2	57.8	56.8	56.0	56.6	60.3	63.8	67.7	70.4	72.1	74.4	77.4	79.1	80.3	80.7	80.3	79.2	76.4	73.0	69.9	67.1	64.9	62.9										296713														
HOURLY LOADS:	1	494	485	466	451	440	449	500	550	606	643	668	700	744	767	785	790	785	768	728	681	637	597	566	537	618										211999													
AUGUST																																																	
HOURLY TEMPERATURES:	1	59.3	58.7	57.3	56.3	55.5	56.1	59.7	63.2	67.1	69.7	71.4	73.7	76.8	78.4	79.6	78.5	75.7	72.4	69.3	66.5	64.3	62.3											336508															
HOURLY LOADS:	1	486	477	458	444	433	442	493	542	597	634	659	691	734	757	775	780	775	759	719	672	628	589	558	530	610										211999													
SEPTEMBER																																																	
HOURLY TEMPERATURES:	1	59.3	58.8	57.5	56.5	55.7	56.3	59.8	63.2	66.9	69.5	71.1	73.3	76.3	77.8	79.0	79.4	79.0	77.9	75.2	72.0	69.0	66.3	64.2	62.3										296713														
HOURLY LOADS:	1	487	479	460	447	435	444	494	542	595	631	654	685	727	749	767	772	767	751	712	667	625	586	556	529	607										211999													
OCTOBER																																																	
HOURLY TEMPERATURES:	1	55.2	54.7	53.4	52.5	51.8	52.4	55.6	58.8	62.3	64.6	66.2	68.2	71.0	72.4	73.6	73.9	73.6	72.5	70.0	67.0	64.2	61.7	59.8	58.0										285012														
HOURLY LOADS:	1	428	421	403	390	380	388	434	479	529	562	584	613	652	673	689	694	689	674	638	596	557	521	493	468	540										296713													
NOVEMBER																																																	
HOURLY TEMPERATURES:	1	49.0	48.5	47.4	46.6	45.9	46.4	49.4	52.3	55.4	57.6	59.0	60.8	63.3	64.7	65.7	66.0	65.7	64.8	62.5	59.7	57.2	54.9	53.1	51.5										211999														
HOURLY LOADS:	1	340	333	318	306	294	304	346	387	432	462	482	508	544	563	577	582	577	564	531	493	457	424	399	376	442										140507													

Figure 12-8. Storage System Operation, July - Hot Day.



with very little, is that a whole lot can actually be done very little. In this particular case, a significantly large cooling plant was analyzed and a multi-million dollar retrofit project developed, including some reliable baseline information, for just a couple of tens of thousands of dollars. This is on the order of a penny per square foot of facility, or something like 1% of the dollar value of the retrofit. It also underscores our continuing exhortation that investment-grade audits be performed as a part of a performance contract and that investment-grade audits are not prohibitively expensive (though they are costly) and are the best possible "insurance" which can be purchased for a performance contract.

Chapter 13

Performance Contract Financial Analysis

Steve Kromer, Teton Energy Partners

In Chapter 10 we introduced some general concepts about Measurement and Verification. In Chapter 11 we discussed several of the documents that are available to assist the user in performing M&V and communicating M&V plans and results. In this Chapter we will continue to focus in on the details of a performance contract and some of the tools and methods available to accomplish an effective M&V plan.

The author believes that the most important tool in performance contracting is the computer spreadsheet. (Not to be confused with its paper namesake). The most recent spreadsheet programs allow a thorough and sophisticated portrayal of the essentials of a performance contract. Of course, just because a project is well-documented in a spreadsheet doesn't make it a good project. But there is good reason to question the ESCo or engineer who has not bothered to support their project with such documentation.

A well-built spreadsheet allows the user to audit the concepts and conclusions presented quickly and easily. It makes the reasoning of the engineer transparent. A word processor report, or a poorly built spreadsheet clouds or conceals the facts that justify the project. Why would any honest engineer want to hide the critical assumptions in a project?

Spreadsheets may not be the best tool for every energy calculation (Chapter 14 explains this) but they also allow the user to perform another critical function of project review—sensitivity analysis. Back in the previous chapter when we spoke about optimizing the M&V plan this is what we meant. The only way you can objectively construct a meaningful M&V plan is to understand how the potential/intended measurement weighs into the final answer. Is the measurement of chilled water

supply temperature more important than fan capacity? You can't tell unless you have a tool that allows you to "tweak" the variables and learn how they affect the result.

There are several add-in programs available that allow the user to perform sensitivity analysis, Monte-Carlo simulations and risk assessment.¹ And there are numerous books that provide the theory and practical guides to constructing models.² The theory, methods, and technology exist to support a sophisticated analysis of every ESPC project and program. So why isn't this the norm?

With only a few exceptions, the sophistication of the buyers and sellers of energy projects is not equal. As stated earlier in this book, buyers of energy projects are all too often willing to listen to whatever promises an energy service company makes. And in that situation, the ESCO sales teams fall all over each other to over-promise results. Unless and until buyers of energy services require reasonable, transparent documentation of project value, and reasonable and transparent verification of project performance, the industry will be incentivized to spin tales now and cover up later. On the other hand, when the buyers of energy projects require the energy services company to measure every wire and document every assumption, they have to be aware that this cost will diminish the ESCo's ability to invest in the underlying project. Reasonableness is called for on both sides.

At one point in my career I was witness to a large program having trouble finding this sweet spot. In conjunction with several others we created spreadsheets which would allow the user to change all of the relevant financial and engineering variables to determine the result on the project viability. The echoes of those spreadsheets are floating out on the World Wide Web as I write this. A quick web search for "espc xls" turns up several versions. Appendix D is a printout from the spreadsheet to show very quickly the nature of the inputs needed and the outputs generated (as well as the instruction notes built into the spreadsheet). While this effort never gained wide acceptance within the contracting community at the time, I believe that the long-term health of the industry will require continued improvement in project documentation. (Editor's

¹Decisioneering's Crystal Ball Software and Palisade's@ Risk are two examples.

²*Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*, M. Granger Morgan and Max Henrion, Cambridge University Press is one of the best introductions to the subject.

Note: While it is not broadly known, at least one Fortune 500 performance contractor internally uses a very similar spreadsheet, even live during meetings with clients to do “mix and match” evaluations to see if the owner’s desired infrastructure improvements with little or no payback can be packaged with other quick-payback work. So, this approach has met with significant acceptance, though this particular firm resists sharing the spreadsheet with their clients—a mistake in our opinion.) And if you think you’re saving time and money by not going overboard on documentation, just wait until halfway through the term of the project when you are stuck negotiating adjustments to the baseline without the benefit of the original calculations. I’ll bet you’ll wish you had just such a tool to assist in the calculations.

These past few chapters are merely an introduction to some of the issues you’ll face when you venture into the world of M&V. I hope they have provided some insights into how and why the current set of documents were created and how you can benefit from them. More than I ever would have believed when I started in M&V in 1993, this is a discipline that covers broad areas of engineering, law, risk management and even philosophy. There are few objective, “right answers.” There may be fewer objective purveyors. You will no doubt find your own comfort zone on these issues, and I believe you will enjoy the journey as I much as I have.

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Chapter 14

M&V Software for Option C

John Avina, Abraxas Energy Consulting

INTRODUCTION

The title of this chapter is “M&V Software for Option C,” however, a better title might have been “How to Use M&V Software for the Whole Building Approach.”¹ The objective of this chapter is to present the need for, and the theory and practice behind Utility Bill Analysis (UBA) software that can be used for Option C, Whole Building, M&V. I will do my best to explain the concepts and practice in a simple and hopefully entertaining manner. I hope to present various applications, and also relate some of the compromising situations the practitioners sometimes find themselves in. Readers will also note that our leader in this endeavor, Jim Waltz, has already lightly addressed this topic in Chapter 12. Having himself created a software program to do Utility Bill Analysis nearly 20 years ago (the *Energy Accounting Report System*), he knows the subject well. I am honored that he has asked me to address the subject in some depth.

I work with both sides of the performance contracting industry, and overall, think performance contracting is an excellent business, and an excellent offering to cash-strapped organizations, which need new mechanical equipment or energy management guidance, provided that it is

¹At the time this chapter was written (October 2002), there was only one software package available on the market that conforms to FEMP Guidelines and ASHRAE Guideline 14P, Metrix Utility Accounting System.” All general mention of UBA software refers, in actuality, to Metrix version 3.1, the most current version at the time of this writing. It is hoped that if any other M&V software packages are written in the future that they will live up to, or surpass, the bar set by Metrix.

done in good faith. One of the places the deal can break down is in the practice of M&V. In order to avoid costly blunders, it is very important for performance contractors and their customers to understand M&V. If you know the rules of the game, you have a better chance of winning. And in a good performance contract, everybody can win.

Perhaps one of the greatest benefits of UBA is that on a visceral level, comparing utility bills is what tracking savings is all about. Before, the customer used a large amount of energy. Now he uses less. The bills will tell the story. Either the customer saved energy or he did not. That is what performance contracting is all about. In my opinion, the customer wants to see the savings in his bills, not on some spreadsheet (Option A or B) or modeling program (Option D). (*Editor's Note: See Chapter 9 on case studies for further confirmation of this somewhat typical Owner's bias.*) Although there are plenty of reasons to choose the other approaches, at a high level, Option B is conceptually the simplest and most direct method. However as we delve into the details of Option C, we will discover that it can be difficult, tedious and occasionally morally challenging.

THE FAMOUS MAN'S ROAD SHOW

When I was still a beginner at energy analysis, I saw a lecture from a nice man who was famous in M&V circles. He was explaining to an auditorium full of people how simple M&V is. His demo went like this: He would turn on three 100-Watt incandescent light bulbs, and ask us how much power was being used. We got out our calculators and figured it out, 3×100 Watts = 300 Watts. That is how much energy they used to use. Then he replaced the bulbs with fluorescents, which were maybe 25 Watts. He turned them on. Then he asked us again how much energy was being used. We figured that out too, although it was harder, 3×25 Watts is 75 Watts. Now he asked, how much energy were we saving? Let's see, 300 Watts minus 75 Watts, uh, how about 225 Watts? Right! So, we figured it out. This was the essence of M&V. See it's not that bad. Anyone can do it. Even us!

I think he was trying to explain to the crowd that M&V is simple, energy usage before minus energy usage after and you get savings. But if it is so simple, how come they hire engineering graduates to determine savings? And how come, when it comes to explaining cost avoidance to

customers, the customer is often left confused? How can you confuse someone with "Old Usage minus New Usage equals Savings"?

Well, I think the answer is that M&V really isn't so simple after all. Read on and you will see.

NOTHING IS EVER AS EASY AS IT SOUNDS

Suppose your job is to prove savings for 100 schools because your company performed energy savings lighting, DHW, swimming pool, and controls retrofits on every school. Assume that each school has, on average, 5 meters. The first step, then, would be to gather bills for about 500 meters. This seems simple, right? But who is going to give you the bills? Some customers are very organized, and their accounting departments have the bills and will make copies for you. Some customers are unorganized and either cannot find the bills, or have lost several bills. You won't get them all. So you go to the utility, and after much red tape, you might be able to get bills faxed to you, but then again, you might not. There is also the added difficulty of knowing which accounts to track. Often, neither the utility nor the customer knows which meters are associated with which buildings or which parts of those buildings. Just determining which bills you want to track and then getting all the bills you need is rarely easy. Believe me.

Now for the hard part of bill tracking: Some schools get new meters when they add portable buildings (seems to happen every year). Some schools just add new portable buildings to existing meters. Some schools are demolishing buildings and closing accounts. Some schools are missing utility bills. Some schools are trying a new summer school program this year. Other schools were closed down last year for a few months after the earthquake, and shifted their populations to other schools. On top of this, the utility has to complicate things as well. The utility might change out meters (changing meter numbers) on some schools, and on other schools, the utility will change the account numbers and you will not be told. You will just have to figure out why several accounts no longer have bills and why several new accounts were established. Then you will have to match the old accounts to the new accounts. This happens all the time. Do you get the point? Complexity! Tracking bills and trying to account for all these changes can be very tedious if not overwhelming. Each school taken by itself may be somewhat easy. But just

try tracking all 100 schools. What a mess! The famous man didn't mention this. I remember talking to one energy analyst who was so overwhelmed, he didn't know where to start and for weeks was asking for advice from anyone who would listen. He was very unhappy.

So what have we done so far? We have gotten our hands on utility bills, and tried to keep track of all the changes going on in a school district. This is all simple in concept, but in actuality it is tedious and difficult work. We haven't even gotten to the math part yet. I hope I have convinced you, the famous man wasn't really telling the whole story. UBA isn't so easy—perhaps it is conceptually easy, but not easy in practice. Let's move on.

WHERE UBA FITS INTO IPMVP

According to the IPMVP, Option C should be applied in cases where there are either several retrofits affecting one meter, or retrofits that interact with each other, or perhaps multi-faceted retrofits which affect so many systems in a building that it would be too difficult or costly to measure savings using retrofit isolation.

Each performance contract will apply whatever option the performance contractor and his customer both agree is best for the situation. UBA is best for some customers because it can be less expensive than retrofit isolation and, at first glance, it isn't confusing with obscure mathematical and engineering mumbo-jumbo. UBA is best for some performance contractors because it can be a standardized method, can be less costly and lessens the risks of changes in weather, misunderstandings and blunders.

One problem with the Options A, B, and D, is that, no matter how much cost avoidance the contractor claims is accruing, the customer will inevitably come back to the contractor with his utility bills and ask the contractor to show him the savings in the bills—and there may not be any energy savings in the utility bills.

BENEFITS AND DRAWBACKS OF UBA APPROACH

UBA has many benefits, including high-level simplicity, cost, and accuracy. Some drawbacks would be difficulty explaining low-level details to customers, the difficulty in creating baseline modifications, and cost.

Simplicity and Complexity

UBA is the obvious choice for the Performance Contracting customer. The customer wanted to see his utility bills lowered. That is the reason he entered the contract in the first place. So naturally, he would expect to see results in a simple comparison of utility bills. The process is simple. On the other hand, if the performance contractor performs weather correction in the savings calculations, then, the customer could get confused. At times, weather correction is difficult to explain.

Inexpensive yet Expensive

UBA can be relatively inexpensive compared to retrofit isolation, but it can cost more than one might expect. It is likely that the entire cost to perform UBA is labor alone, and much of it can be done with clerical workers. At first thought, you might think, how much work can it be to compare last year's bills to this year's bills? But, unfortunately, it can be more complex than just comparing bills. The idea behind UBA is that you want to compare pre-retrofit bills to post-retrofit bills for the *same meter*. But if the customer transforms storage space into a computer lab, and adds a new wing to the building, and the meter is picking up all this new load, then is this still the same meter? I don't think so. It is an unfair comparison. And in order to make the comparison fair, you will have to make some kind of adjustment to account for the new computer lab and the new wing the customer just built. We will cover this later. But the point here is that whoever is doing the simple utility bill tracking also has to keep tabs on the building and note all changes that are made in the building's energy consumption profile, including the overriding of set points, renovations, new equipment, changes in schedules, etc. This takes time, and therefore money.

Randomness

There is a certain amount of randomness in UBA. So many factors influence the amount of energy usage in any given month, and they cannot all be accounted for. As a result, if you are trying to show savings that is less than 10 or 15% of the total electricity load, then the randomness may seriously affect your numbers. In fact some of the M&V Guidelines suggest you not use utility bill analysis if your savings targets are less than 10% to 20% of total usage.

Inability to Separate Out ECM's

If you track savings by comparing utility bills, you will only be able to track total savings for a given meter, but you will not be able to separate out the savings for different Energy Conservation Measures (ECM's). For example, if you installed a lighting retrofit, an energy efficient chiller and a control system in a hospital, you will not be able to tell how much energy is being saved by the control system. People do try to break out the savings for each ECM occasionally, but they are only making educated guesses.

Interactive Effects

Option C will collect all interactive effects. However, on the other hand, if you use Option B to verify your savings, you may not gather all the interactive effects. For example, a lighting retrofit may affect the energy usage of the chiller, the boiler, fans on variable speed drives or fans that cycle, and maybe even chilled water pumps and hot water pumps. Are they going to put sensors on all of this equipment for a lighting retrofit? If so, then it might be less expensive to just use Option C.

Overall Assessment

We all have our biases, and as you may have figured by now, I am biased towards UBA for verifying savings, mostly at a visceral level. The customer wants to see the savings in his bills, not on some spreadsheet, contract or building model. Also, it just appears to be the most honest method to me. But believe me, there are plenty of ways for the customer and contractor to practice deception using this method. (*Editor's Note: Readers may want to take a peek at Section 17.3 as well—there is little unanimity in this M&V business.*)

WHERE IS THE SAVINGS?

I previously said a drawback of retrofit isolation is that the performance contractor might claim there is cost avoidance (which sounds like savings to most of us), and the spreadsheets might say there is cost avoidance, but the utility bills might not show cost savings. The customer might feel cheated, and then the contractor and customers could enter into the death struggle.

Part of this misunderstanding may be associated with the term,

“Cost Avoidance.” Cost avoidance is not the same as “Cost Savings.” Energy savings and cost savings are what you see when you compare old utility bills to new utility bills. The difference is savings (or an increase), just like the nice man explained in the seminar. The problem is that there is no way to directly measure Energy or Cost Savings since we don’t have any instruments to measure what was not used. We can, though, measure cost avoidance. Cost avoidance is the difference between how much money you would have paid if the ECM’s had not been taken and how much money you actually did pay (now that the ECM’s were initiated).

What’s the difference between savings and avoidance? Suppose you lived in California, and to pay for the deregulation fiasco, your electricity rates were increased by 30% on 2002’s bills. Now suppose you had initiated a program of turning off equipment in your building, and you figured you must have saved about 10% of energy usage. When comparing this 2002’s bills to 2001’s bills, you might see a 10% drop in energy usage, but you will see an increase in total costs due to the 30% increase in the electricity rates. Your cost savings are negative. But if you hadn’t initiated your energy savings program, the costs would have been about 10% higher. Your cost avoidance is that 10% more that you would have paid had you not initiated your energy savings program. I will spell it out below:

Cost Savings	= Last Year’s Bill	- This Year’s Bill
Cost Avoidance	= What This Year’s Bill Could Have Been	- This Year’s Bill

Many of us in the industry, including myself up to this point, use the term “Cost Savings” when we mean “Cost Avoidance.” “Cost Avoidance” is more correct, though. So for the remainder of this chapter, we will try our best to use the two terms correctly.

WHY USE WEATHER CORRECTION?

Have you ever had the feeling that some professionals try to make things as complex as possible just to keep themselves in a job? Accountants? Tax lawyers? Try understanding your electricity bill. If you live in

California, you will likely have to call the utility to get help figuring out how they calculated your total bill. Why can't they just keep it simple and charge us \$0.15/kWh? Well, that is how some people feel about UBA.

As mentioned before, the basic concept is to compare pre-retrofit bills to post-retrofit bills. This is so simple. So why did they have to go and muck it all up with all this statistical nonsense? There is good reason behind this madness.

First, let me explain what could happen if you didn't have weather correction. Suppose a performance contractor installed an energy efficient lighting retrofit in a customer's store. Everyone would have expected to see energy and cost savings from this retrofit. For June the customer might expect savings from June's utility bill as shown in Figure 14-1, and Table 14-1:

Table 14-1 Expected Pre- and Post-Retrofit Usage for Lighting Retrofit Example

June 2001	179,359 kWh
June 2002	152,455 kWh
Savings	26,904 kWh

But what if, instead the customer saw the numbers in Table 14-2 and Figure 14-2?

Table 14-2 Unexpected Pre- and Post-Retrofit Usage for Lighting Retrofit Example

June 2001	179,359 kWh
June 2002	197,295 kWh
Increase	-17,936 kWh

The customer, when seeing the numbers, could conclude that the energy efficient lighting was actually using more electricity than the older less efficient lighting. It might appear that the contractor screwed up.

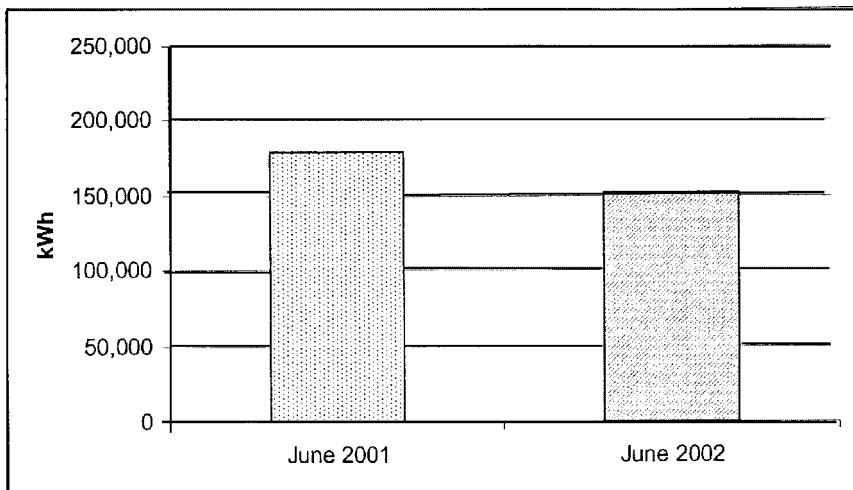


Figure 14-1. Expected Pre- and Post-Retrofit usage for lighting retrofit example. After a lighting retrofit, you expect to see energy savings.

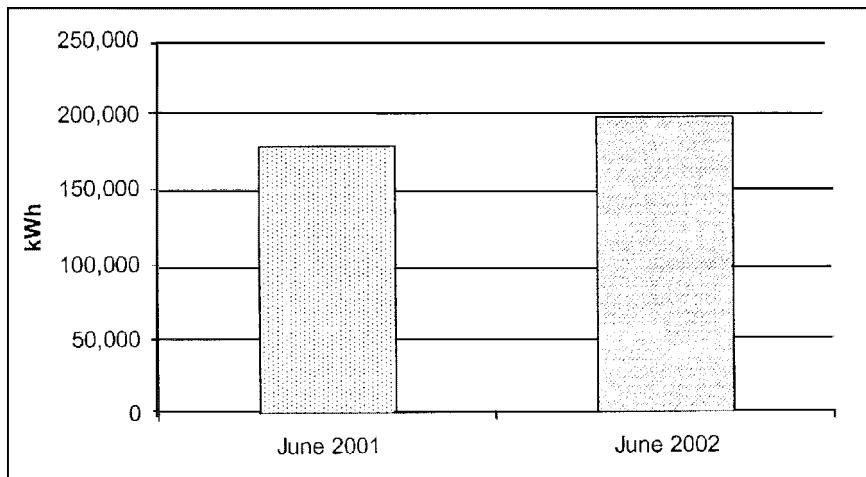


Figure 14-2. Pre- and Post-Retrofit usage for lighting retrofit example. In this case, even though a lighting retrofit was put into place, there is an increase in energy usage.

There are several reasons this could have occurred. One reason could be that June 2002 was much hotter than June 2001, and the air conditioning load would then be much greater, which could have resulted in increased utility bills. If this were true, then how could you ever measure savings from energy efficiency projects? You would be at the mercy of the weather.

It would be much easier to show the reduction in energy usage if you could somehow remove weather from the entire equation. Then it wouldn't matter if it was hot one summer or the next. If you saved energy you would see energy avoidance in your comparisons.

Many companies do just this thing. They remove weather from the avoidance equation because they want to be able to prove that they are actually reducing energy usage (if indeed they are). Imagine if you were a performance contractor and you were going to share cost savings with your customer. During hot years, there would be no savings to share. You would be at the mercy of the weather. No company wants their cash flow to depend upon the weather, or to take the risk of a permanent climate change, if they don't have to. As a result, many of the top performance contracting companies weather-normalize their savings to balance cash flow and reduce risk.

This process has many names, and is called weather correction, weather normalization, tuning to weather, tuning, or weather regression.

UTILITY BILL COMPARISON

Some ESCo's are willing to take the chance on weather and will just compare utility bills without normalizing to weather. This can easily and simply be done with spreadsheets. Their thinking is that over a 10 or 20-year contract, the fluctuations in weather will even out. If the contractor is large, then hot summers in some regions would balance out with cool summers in other regions, such that the entire portfolio of buildings under contract would not vary too much with weather. There are a couple of benefits to this approach: Bill comparison is less expensive than UBA. One should not underestimate the importance of the simplicity of Bill Comparison. This method is easier to communicate to the customer, which can foster a more trusting relationship between customer and contractor. If the customer doesn't understand how the contractor got the savings numbers, then he might not trust the contractor.

There are some shortcomings to the Bill Comparison method. Consider a hypothetical case where the weather was extreme for the first two years of the contract. The performance contractor might explain to the customer that because of the weather, there wasn't any energy or cost savings at all, because the extra air conditioning and heating required during these extreme years ate into the savings that the ECM's provided. This explanation could be true in some cases, however, how would the contractor know for sure, if they didn't bother to separate out the variation in usage due to weather? The reason for the increases in usage could have also been due to changes in building usage patterns, or perhaps the retrofits were just not working. But if the contractor is not alarmed about the lack of savings (because the weather was extreme after all), then he will be less likely to investigate the effectiveness of the retrofits, until, perhaps, it is too late, and years of potential cost avoidance was lost. Depending upon how the contract is structured, this could hurt both the customer and the contractor.

Although the large contractor may not need weather correction to balance cash flow and control risk, it is still reassuring to the customer to see savings year after year. If savings only occurs on average or mild years, the customer may not feel as confident about the contract. In addition, the customer who advocated the performance contract to his management may be assigned personal responsibility for the effectiveness of the contract. How would this customer explain the lack of savings to his management? "Oh, yes, we have installed all this energy savings equipment, and we are saving energy, but our utility bills are higher because the last two years have been very hot. The contractor said this is normal and not to worry." Do you think management would buy that? Maybe they would just get a new energy manager.

Perhaps it is for some of these reasons that FEMP Guidelines calls Utility Bill Comparison an "unreliable method," and recommends that it not be used in most federal ESPC projects. In place of Utility Bill Comparison, FEMP Guidelines suggests the weather regression approach be used.²

OTHER SPREADSHEET APPROACHES

Some ESCo's use spreadsheets to calculate their cost avoidance

²M&V Guidelines: Measurement and Verification for Federal Energy Projects, Version 2.2, Chapter 21, Section 21.1, p. 165

using utility bills. Although I will admit having done this myself, I don't think it is a good approach. I have seen several spreadsheets, some of which account for weather in their cost avoidance calculations, but none of these conform to generally accepted methods as documented in the FEMP Guidelines or ASHRAE Guideline 14P. Not only that, some of these spreadsheets have very questionable methods and assumptions. Usually the spreadsheets are created by sharp analysts, but sometimes they are created by unsophisticated people. I have seen spreadsheets that would make most M&V specialists laugh. (No, I didn't create them.)

The other drawback of spreadsheets is complexity. A while back, I was hired by a company to decipher a monster that sprawled out over 30 worksheets, one of which had data covering over 60 columns. What happens when the creator of monsters like this leave the company? Who will understand the method and the spreadsheet enough to continue using it? These were the questions my clients were asking themselves when they hired me.

The other rap on spreadsheets is that they are usually used by very few people. The more people who use a program or spreadsheet, the more likely it is that all bugs will be found. When a spreadsheet is used by just a few people, bugs sometimes just don't get found. For this reason, among others, if weather correction is used, I recommend canned utility bill analysis software.

What if there was an honest mistake in the spreadsheet, and for several years the ESCo accidentally claimed more savings for a project than actually occurred. I am sure this has happened here and there. Now, what if the customer figures it out and tries to sue the ESCo. I guess the ESCo has no one to blame, and has to bear the consequences for their mistake, since they made the spreadsheet. I would think it would be more comforting to the ESCo's to use canned software for this reason. The software would follow the recommended methods, and the bugs, if any, would not be seen as the fault of the ESCo's at all.

CANNED UTILITY BILL ANALYSIS SOFTWARE

In my opinion, if you are going to perform UBA for a performance contract, you should use canned UBA software. However, you have to find the right software.

Some software packages specialize more in "bill tracking." These

software packages compare bills by year, for example, June 2000 to June 2001, and have no concept of baseline. These packages don't allow you to add baseline modifications, and although they may claim to perform weather regression, their weather regression routines are black boxes and weak if not laughable, and certainly do not meet ASHRAE Guideline 14P standards. These packages are wonderful applications for bill tracking or budgeting, just not for M&V.

There is only one software package for sale at the time of this writing that actually does meet IPMVP, FEMP and ASHRAE Guideline 14P standards and was written specifically to determine cost avoidance, rather than to just track and compare bills. Metrix Utility Accounting System" was first released in 1996. The software has the several features which make it the leading UBA software package. These are:

- Capability to regress utility usage against up to 5 variables including weather and user-determined variables.
- Proration of usage by number of days. If the current bill has 34 days, then the comparison is made to a baseline 34-day bill.
- Reporting of ASHRAE Guideline-14P statistical criteria (i.e. R^2 , CVRMSE, Mean Bias Error)
- Capability to add modifications to the baseline
- Capability to model utility rates
- Capability to apply different rates to different scenarios (i.e., if the customer was on Rate A, and the contractor switched the customer to Rate B)
- Excellent reports made specifically for performance contracts.

HOW WEATHER REGRESSION WORKS

The entire concept of weather normalization centers on the concept of Baseline. Baseline consumption is the amount of energy your building would have used given today's conditions, where today's conditions refer to length of billing periods, weather conditions and how the build-

ing is operated now. (Let's keep it simple for now, and leave billing days and building operations out of it for now.) Energy Avoidance, then, is Baseline consumption (or how much energy your building would have used) minus Actual consumption (or how much energy your building did use).

Before you can determine the Baseline, you have to model pre-retrofit energy usage patterns, that is, perform a weather regression on pre-retrofit bill data. To do this, you select one or two years of bills from before the retrofit took place. Once you have your bills, you can graph them against weather as shown in Figure 14-3.

Notice in Figure 14-3, that the x-axis is cooling degree days (CDDs). For the sake of simplicity, for now, let's define CDDs as a simplified way that engineers measure weather data. Hotter periods that require more air conditioning will have more CDDs. Winter periods in which there is no air conditioning, will have 0 CDDs. We will cover CDDs in greater detail in a later section.

In Figure 14-3, you may notice that kWh and Cooling Degree Days (CDD) are divided by number of days. This is done so that all bills are represented fairly. If one bill had 45 days, and another had 30 days, then because the bills are being divided by number of days, we are looking at comparable quantities, the average kWh/day per bill and the average CDD/day per bill. If we didn't divide by number of days, then there would be no trend in the graph, and bills with more days would have extended higher in the graph than bills with fewer days.

In Figure 14-3 below, the points represent bills. Notice that as there are more CDDs (in other words, as it gets hotter), there is more energy usage. This means that electricity is likely used to cool the building. Notice also that the relationship between energy and CDD appears linear. This is common. The M&V software found the line that comes closest to all the points. This line is called the "best-fit line." This "best-fit line," then, can represent the points in the graph, or even better, since the points are all pre-retrofit bills, the best-fit line represents the energy usage of the meter before the retrofit takes place.

For example, given Figure 14-4 below, if there was a billing period, say June 2001, with 30 days and 750 CDDs (which would be $750 \text{ CDDs} / 30 \text{ days} = 25 \text{ CDDs/Day}$), then our fit line predicts that the meter would have used about 7500 kWh/Day or $7500 \text{ kWh/Day} * 30 \text{ Days} = \text{about } 225,000 \text{ kWh}$. I have drawn a line over the tuning graph to show how from 25 CDD/Day we were able to get estimate that the building would

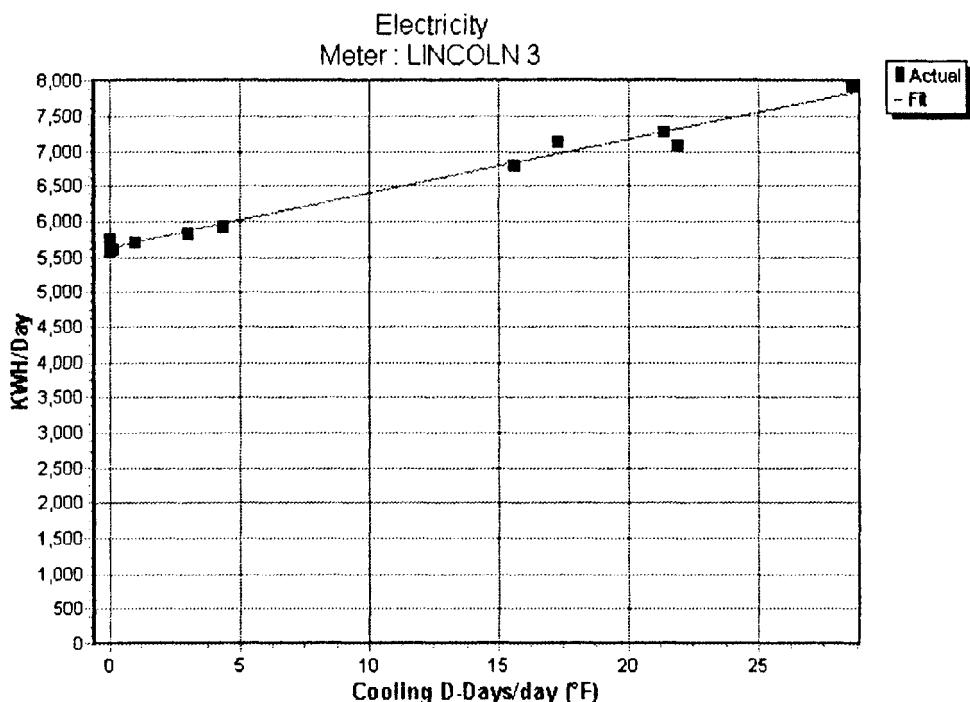


Figure 14-3. Tuning Graph. In order to determine the relationship between bills and weather, normalized bills (kWh/day) are plotted against normalized weather (Cooling D-Days/day).

have used about 7500 kWh/Day.

This can also be calculated mathematically, rather than graphically. But before we do this, first we have to introduce the fit line equation. You may remember in those high school algebra classes that every line has an equation. The equation for a line is

$$y = mx + b$$

where m represents the slope of the line, and b represents the y-intercept (where the line crosses the y-axis).

In our graph above, the y-intercept is 5619.3 kWh/Day. You can see that the line does cross the y-axis at about 5619.3. The slope of the line is 74.16 kWh/CDD. (You will have to take my word on that.) If we insert these numbers into the fit line equation above, we get

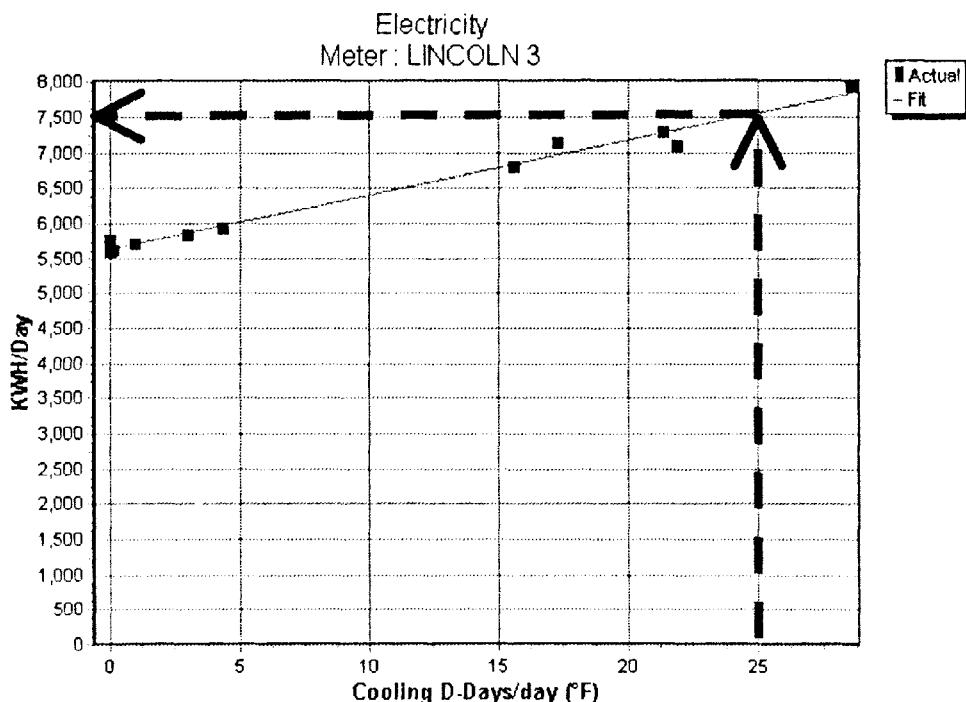


Figure 14-4. Tuning Graph. Dashed lines have been added to show how Baseline kWh can be graphically determined if you know the number of CDDs in the billing period.

$$y = m * x + b$$

$$\text{kWh} = 74.16 \text{ kWh/CDD} * N_{\text{CDD}} + 5619.3 \text{ kWh/Day} * N_{\text{days}}$$

Where N_{CDD} = number of CDDs in a billing period, and N_{days} is the number of days in the billing period.

In our example in Figure 14-4, we assumed there was a 30-day billing period and 750 CDDs in the 30-day billing period. Then, rather than using the graph, we could use the fit line equation to calculate Baseline energy usage:

$$\begin{aligned}
 y &= m * x + b \\
 \text{kWh} &= 74.16 \text{ kWh/CDD} * 750 + 5619.3 \text{ kWh/Day} * 30 \\
 &= 55,620 \text{ kWh} + 168,579 \text{ kWh} \\
 &= 224,199 \text{ kWh}
 \end{aligned}$$

which is just about the same number we estimated when we did this graphically.

Since we are calculating numbers, I will restate what we have just done in words. We took some bills from some prior period in time, and we graphed them against weather. We then found a “best-fit line” which represents those bills, and we found an equation which represents that line. So, if the line represents the bills, and the equation represents the line, then the equation represents the bills, doesn’t it? So that fit line equation, then, represents the bills from some prior period of time, or in other words, they represent how the building used to consume energy during that base year.

So, suppose someone installed a lighting retrofit on this building. And we expect that the building should now be using less energy for some post-retrofit month, say June 2001. In fact, suppose we received a bill for 197,295 kWh. Remember from above, we cannot just compare old bills to new bills, because weather could foul the whole calculation up. So instead, we compare “how much energy would have been used given June 2001’s weather” against “how much energy actually was used in June 2001,” or in other words, Baseline minus Actual.

We just figured out how much energy “would have been used” given June 2001’s weather. We took the number of days in the June bill and the number of CDDs. We plugged those into the fit line equation, and then we calculated the kWh that would have been used during the base year, given June 2001’s conditions. We call this amount Baseline usage.

$$\begin{aligned}
 \text{Energy Avoidance} &= \text{How much energy} & - & \text{How much} \\
 \text{for June 2001} & \text{would have been used} & & \text{energy was used} \\
 &= \text{Baseline} & - & \text{Actual} \\
 &= 74.16 \text{ kWh/CDD} * 750 \text{ CDD} - & & \text{The actual bill} \\
 & \quad + 5619.3 \text{ kWh/Day} * 30 \text{ Days} & & \text{from June 2001} \\
 &= 224,199 \text{ kWh} & - & 197,295 \text{ kWh} \\
 &= 26,904 \text{ kWh}
 \end{aligned}$$

Rather than present the results from Figure 14-1 or Figure 14-2, if we used weather regression, we would have presented the results shown in Table 14-3 and Figure 14-5.

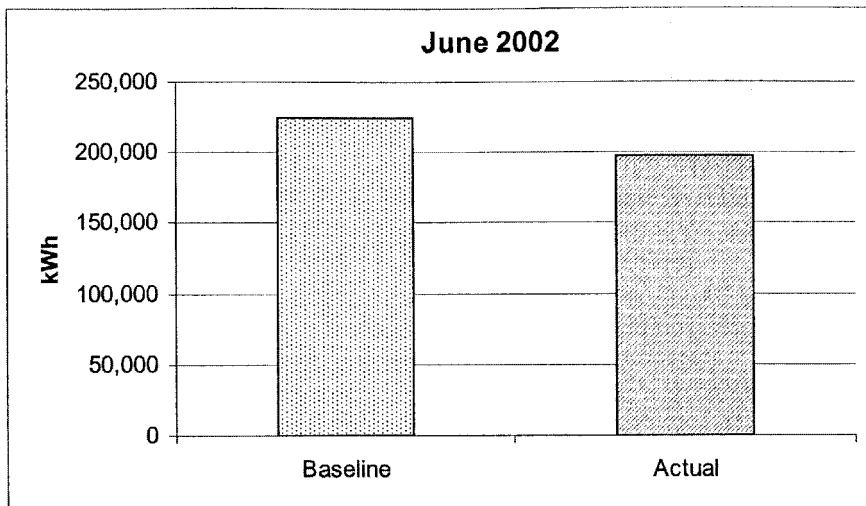


Figure 14-5. Baseline and Actual Usage for lighting retrofit example. Baseline represents how much energy would have been used before the lighting retrofit, given this year's weather conditions. Actual kWh can be found on the utility bill, and represents how much energy actually was used.

Table 14-3. Baseline and Actual Usage for Lighting Retrofit Example

Baseline	224,199 kWh
Actual	197,295 kWh
Avoidance	26,904 kWh

THE REGRESSION EQUATION IN ITS ENTIRETY

The regression equation is larger than what I have shown you so far. Good M&V software allows you to regress against not only one variable, but up to 5 variables. Most practitioners only use 1 to 3 variables, and that is enough. It is rare, or seldom necessary, to see more variables used. The most commonly used variables I have seen are CDDs, heating degree days (HDDs), and number of school days (from the school calendar). The regression equation in its entirety is:

$$\begin{aligned} \text{Usage} = & \text{ Coef}_{\text{CDD}} * \text{N}_{\text{CDD}} + \text{Coef}_{\text{HDD}} * \text{N}_{\text{HDD}} + \text{Coef}_{\text{Var1}} * \text{N}_{\text{Var1}} \\ & + \text{Coef}_{\text{Var2}} * \text{N}_{\text{Var2}} + \text{Coef}_{\text{Var3}} * \text{N}_{\text{Var3}} + \text{Constant} * \text{N}_{\text{days}} \end{aligned}$$

where $\text{Coef}_{\text{Var1}}$, $\text{Coef}_{\text{Var2}}$, $\text{Coef}_{\text{Var3}}$ are the user variables that are usually not used, and N represents “number of.”

Because the meter tunes only for CDDs in our example, the coefficients for HDDs and Var1, Var2, and Var3 all equal 0, and the equation reduces to:

$$\begin{aligned} \text{Usage} = & \text{ Coef}_{\text{CDD}} * \text{N}_{\text{CDD}} & \text{Constant} * \text{N}_{\text{days}} \\ \text{kWh} = & 74.16 \text{ kWh/CDD} * \text{N}_{\text{CDD}} & + 5619.3 * \text{N}_{\text{days}} \\ & & \text{kWh/Day} \\ y = & m * x + B \end{aligned}$$

GLEANING USEFUL INFORMATION FROM THE REGRESSION EQUATION

Some energy engineers use UBA software not just for cost avoidance, but they find UBA useful in understanding the buildings they are auditing. Good UBA provides an excellent first take on the building. Some engineers even use the regression equation to create “quick and dirty” building models or when calibrating detailed building models.

From this simple tuning we can conclude the following: The loads served by the Lincoln 3 meter are mostly Baseload (i.e., essentially independent of weather effects). There is only a small weather-sensitive component in the loads. During the Base Year, electric cooling took place from the end of May through early November. There is no electric heating associated with this meter. Fans are most likely constant volume.

When there is just one independent variable, which in our example was CDD, then the baseline equation can be broken up into pieces to help you understand your building’s energy usage.

$$\begin{aligned} y = & m * x + B \\ \text{kWh} = & 74.16 \text{ kWh/CDD} * \text{N}_{\text{CDD}} + 5619.3 \text{ kWh/Day} * \text{N}_{\text{days}} \\ \text{Usage} = & \text{Temperature-Sensitive Usage} & + \text{Non Temperature-Sensitive Usage} \\ & & \text{(or Baseload)} \end{aligned}$$

The mx term ($74.16 \text{ kWh/CDD} * N_{\text{CDD}}$) represents the temperature-sensitive usage of the building (chillers, package cooling units, cooling towers, etc.), and the b term ($5619.3 \text{ kWh/Day} * N_{\text{day}}$) represents the Non-Temperature-Sensitive Usage of the building (lights, computers, sump pumps, etc.). Figures 14-6 and 14-7, although in different formats, use the same data and illustrate this concept. In Figure 14-6, all usage below the thick horizontal line is Non-Temperature-Sensitive Usage. All usage above the thick horizontal line but below the fit line is Temperature-Sensitive Usage.

When there is more than one independent variable, then it is usually not possible to break the fit line equation into the understandable parts (Weather-Sensitive and Non-Weather-Sensitive Consumption).

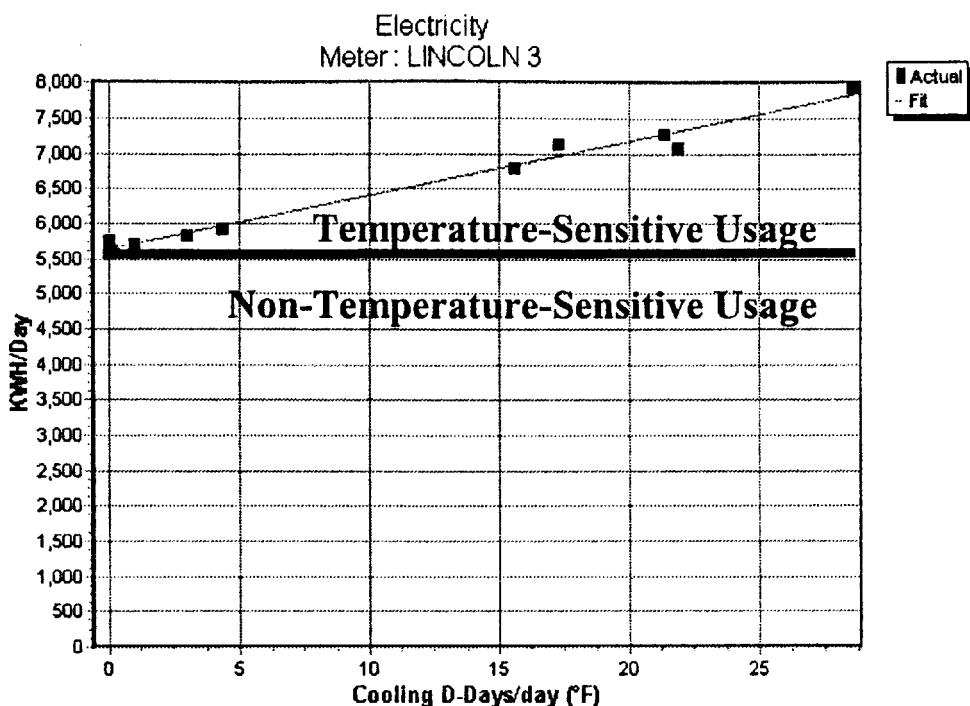


Figure 14-6. Tuning Graph broken into Non-Temperature-Sensitive Usage and Temperature-Sensitive Usage regions.

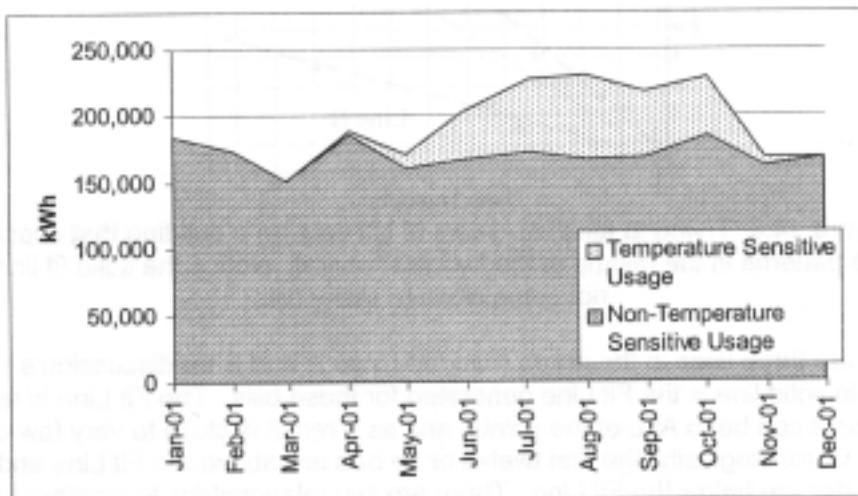


Figure 14-7. Monthly breakout into Temperature-Sensitive and Non-Temperature-Sensitive Usage. This graph shows the same data as Figure 14-6, but in a different format.

A DEEPER LOOK INTO THE PROCESS OF WEATHER REGRESSION

So far we have looked at weather regression in a general sense—now for some details. This section covers the selection of Base Year, the relationship between degree days and balance point, finding the best regression, and some statistical measures for the quality of the regression.

Selection of Base Year

The first step a performance contractor takes when tuning a meter (performing weather regression) is deciding how many and which bills to tune (regress). Some experts will tell you that two years of bills is better than one, and maybe even three years is better than two. In my experience, one year is best. Buildings keep changing—remodels, new equipment, new building engineers, different occupancy schedules and tenants. Because building energy usage often changes from year to year, it is sometimes difficult to fit a line through two years of bills. Figure 14-8 presents a more extreme example below:

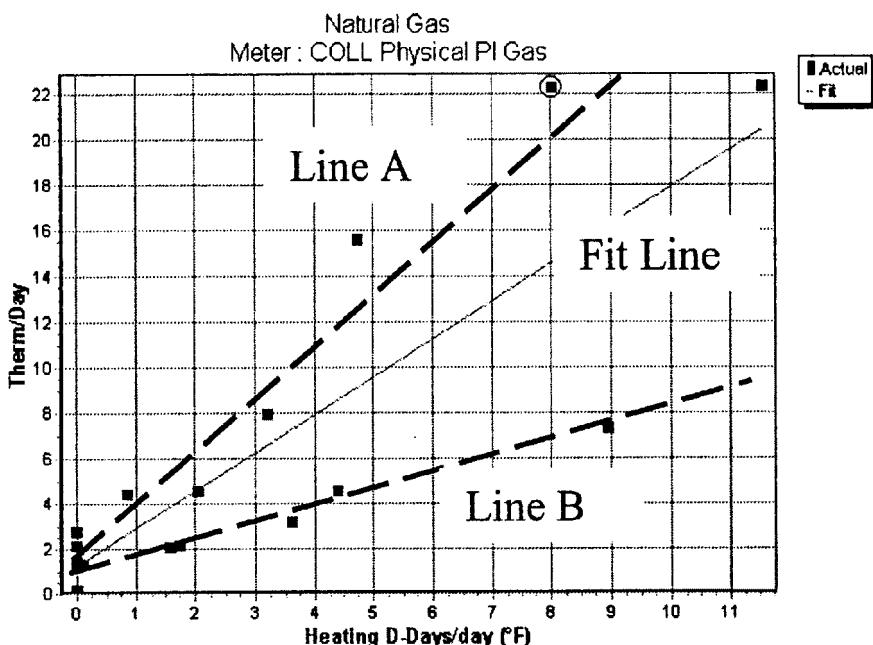


Figure 14-8. Trying to tune two years of bill data on a building that changed usage patterns in the middle of the two-year period. Notice the solid fit line does not come close to many bills.

There are three lines in the graph (I added Lines A and B for discussion's sake). The thin solid line is the Fit Line generated for these bills. The Fit Line is as close as it can be to ALL of the points, and as a result is close to very few of them. Chronologically, the first twelve or so bills are above the Fit Line and the remainder are below the Fit Line. There are two relationships to weather here, and I added the dashed lines (A & B) to the graph to represent these two relationships. The first twelve or so bills represent a meter that does more heating (Line A), while the later bills represents a meter that does less heating (Line B). Either the buildings or heating loop became more efficient, or perhaps buildings were removed from the steam loop, which caused a reduction in heating usage. In any case, there was a drastic change in gas usage in the physical plant. It looks as if either year would have tuned well (the Lines A & B come very close to the points in the graph) and very differently. But if you tried to tune both years together, the fit line wouldn't be close enough to the bills, and the regression would not have been satis-

factory. (We will talk about what makes a regression satisfactory later, but for now, if the Fit Line is far from most of the bills, then the tuning is likely not acceptable.)

Remember the Fit Line is supposed to represent how the building used energy before the ECM's were installed. Tuning for two years in this case doesn't represent the meter's energy usage patterns ever, rather that tuning would represent an average of two very different energy usage patterns.

Recognize as well that if the contractor, when tuning this meter, can decide to tune for any 12 bills in chronological order from this group of 24 bills or all 24 bills, but to keep the discussion simple, let's assume the contractor can tune only 2 different groups of bills: the first 12 bills and the last 12 bills. If the contractor chooses to tune the first 12 bills, the Fit Line might look like Line A. If the contractor chooses to tune for the last 12 bills, the Fit Line might look like Line B. Now suppose there was a 30 day bill with 240 HDDs, which is 8 HDDs/day. Remember how to determine Baseline amounts graphically? Try it on Figure 14-8. For Fit Line = Line A, Baseline therms would be about 20 therms/day or 600 therms. For Fit Line = Fit Line B, Baseline therms would be about 7 therms/day or 210 therms. Now suppose there was a post-retrofit bill for this period of 200 therms. If the contractor had tuned with Fit Line A, then the energy avoidance would have been 400 therms. If the contractor had tuned with Fit Line B, then the energy avoidance would have been 10 therms. Quite a difference! Selection of Base Year period can be very important. I have summarized this comparison in Table 14-4.

Table 14-4. Avoidance Calculations Based Upon Two Different Base Year Selections

<i>Fit Line</i>	<i>Line A</i>	<i>Line B</i>
Current Bill has	30 Days and 240 HDDs	
Baseline therms (determined graphically from Figure 14-8)	600 therms	210 therms
Current Bill therms	200 therms	200 therms
Energy Avoidance	400 therms	10 therms

Since the Baseline is supposed to represent the building before the ECM's were installed, and because buildings change, it is best, whenever possible, to use the last 12 months of bills before the retrofit was installed. Sometimes this doesn't happen because the contract requires a baseline to be documented before the contract is signed, and then sometimes it takes a year or so for everyone to sign the contract, and the Baselines then become representative not of the last 12 months of bills before the retrofit was installed, but rather the last 12 months before the contract was signed. In the meantime, many changes could have occurred in the building.

Sometimes it is not wise to use the last 12 months of bills. This would be true when there was a significant change in energy usage during that period. If this were the case, you would see the same graph just presented, except, rather than 24 bills in the graph, there would be only 12, with some of the bills well above the fit line, and some well below. In this case, you would try to use 12 months of bills after the significant change, that is, if there are 12 months between the change and the installation of the ECM's. Oftentimes, this is not possible, so you are stuck using 12 months of bills before the significant change, and you will have to add a baseline modification to account for the change.

Customers can get an early indication of the truthfulness of their performance contractor when they are presented with the Base Year. Some contractors will select a Base Year that is not the last 12 months before commencement of installation or contract signing. Instead they might choose some previous period that has higher usage. As we saw above, higher Base Year usage usually translates into higher Baselines and therefore into higher Cost Avoidance numbers. Be mindful of which Base Year period is selected and why.

Balance Points

In a gross sense, a building's cooling balance point is the outdoor temperature at which the building starts to cool (see Figures 12-6 and 12-7 for additional insight). A building's heating balance point is the outdoor temperature at which the building starts to heat. The cooling balance point does not have to be the same as the heating balance point. Each building which has temperature-sensitive usage has its own unique balance point. The building's balance point is a function of the building's envelope qualities (are there leaky windows?, how much insulation?, etc.), the building's internal gains (heat generated in the build-

ing by the lights, people and equipment), the amount of ventilation, the thermostat setpoints, and other factors.

Just because we can identify a cooling balance point, at say 60°F, it does not mean that the chiller is switched on when it is 60°F outside. This is a gross generalization that works, as you will see.

Many of us in the energy engineering field think of balance points as a property of a building, because the walls, the people, the setpoints, etc. are properties of the building, and after all it is the building's properties that determine the balance point. But really, the balance point is a property of a meter. The balance point of the meter is determined by the parts of the building that the meter cools or heats. If a meter only serves a warehouse area that is cooled to only 85 degrees, then the meter will likely have a very high cooling balance point, and if a different meter in the same building serves office space on the top floor, then the meter will likely have a much lower cooling balance point, as much more cooling will be required. If a meter serves only light fixtures, then the meter doesn't have a cooling or heating balance point, since the meter doesn't serve any cooling or heating equipment. If a building has several meters, then the building's balance point is some kind of weighted average of the meters' balance points.

Balance Points and Degree Days

In the old days before computers were commonplace, for simplicity's sake, engineers assumed all buildings' heating and cooling balance points were 65°F. When you see heating degree days (HDDs) listed in the newspaper, you are seeing HDDs based upon a 65°F balance point. In UBA, we recognize that each building (or meter) has its own set of balance points. Balance points are important because degree days (which are used in weather correction) are calculated based upon the balance point.

For each day, CDDs are calculated using the equation:

$$\# \text{ CDDs} = (T_{\text{mean}} - T_{\text{Balance Point}}) * N_{\text{day}}^+$$

Where T_{Mean} is the average of the high and low temperature for a day, $T_{\text{Balance Point}}$ is the balance point temperature, $N_{\text{day}} = 1$ (since we are only calculating for 1 day), and the + means that CDD must always be positive. You can never have negative CDDs.

To determine the number of CDDs for each bill, CDDs are calcu-

lated for each day of the billing period and then summed into billing periods.

HDDs are calculated similarly:

$$\# \text{ HDDs} = (T_{\text{Balance Point}} - T_{\text{Mean}}) * N_{\text{day}}$$

Like CDDs, you can never have negative HDDs.

It is not necessary that you remember how degree days are calculated. But it would be helpful to recognize that the number of degree days associated with a building (or meter) is related to the building's (or meter's) balance point.

Determining Balance Points

When performance contractors tune the pre-retrofit bills, part of the process is determining the balance points of the meter. The way to do this is to view the pre-retrofit bill data plotted against average temperature of these billing periods. This is a very gross generalization, but it works.

In Figure 14-9, I have added two dashed lines, a horizontal line, and a slanted line. Since we can see that, as the temperature increases, usage increases, we can conclude that the meter is used to cool. Where the two lines intersect is our first estimate of the meter's balance point—a dotted line is dropped from the intersection to the x-axis, at about 46°F. This intersection separates two different regions in the graph. In the three or four bills to the left of the intersection, we can safely see that there is no temperature-sensitive usage occurring in the building because no matter what the average temperature is, the usage remains relatively constant. To the right of the intersection, as the average temperature increases, usage increases, this tells us that there is temperature-sensitive usage occurring at these higher temperatures in addition to the non temperature-sensitive usage.

Some meters are used to both heat and cool the building. You can tell because as the average temperature increases, there is more usage (cooling), and as the temperature goes down, there is more usage (heating). An example is presented in Figure 14-10.

There are two balance points for this meter, a heating balance point, and a cooling balance point. For meters that both heat and cool, it is harder to determine balance points solely from this graph, and my first estimates of 42°F and 57°F would likely need to be revised. In addition,

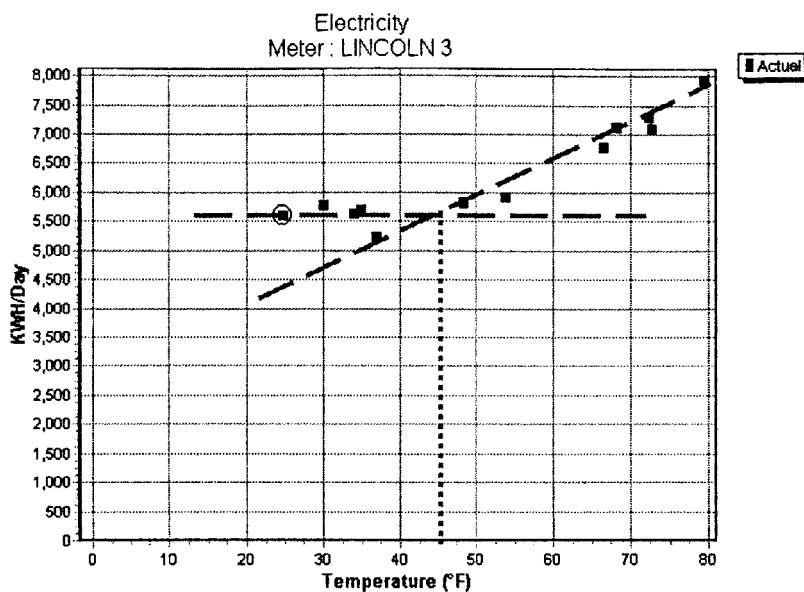


Figure 14-9. Determining the Balance Point, which is often where the two dashed lines meet.

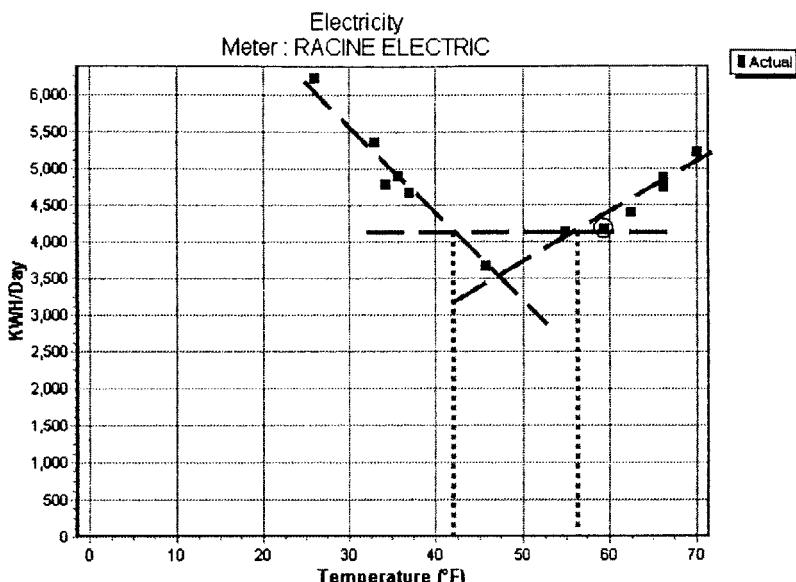


Figure 14-10. Meter is used to heat and cool and has two balance points.

when the meter is used to heat and cool, baseload cannot be determined at all, because for this meter, there may never be a month in which no heating or cooling occurs.

Deselecting Bills from the Tuning

Sometimes not all the bill data is correct. Usually, one can tell right off that a bill is wrong. Figure 14-11 shows a set of bills with an obvious outlier, which I circled (in case you couldn't locate it yourself). The right way to handle this, would be for the contractor to look into why this bill is lower than it should be. Most likely, it is the result of a clerical error. If so, the contractor would get the correct amount and proceed. What if it is not a clerical error? Suppose the building shut down for a few weeks after the volcano blew up. Once the contractor knows the reason for the strange bill, he can proceed. If he tried to tune using all bills, the outlier would pull the fit line down as shown in Figure 14-12. Now, the fit line doesn't come close to any of the bills during the heating season, and for reasons you will discover later, the tuning will be unacceptable. (Remember, the best-fit line is the line that comes closest to ALL points.) Once we remove the outlier, as we did in Figure 14-13, then the best-fit line will shift to where it belongs, and will better approximate the bills during the heating season, and will result in a good tuning.

Now that the aberrant bill has been removed from the tuning, how would this affect the Baseline amount or Usage Avoidance? Since we assumed that this was a one-time occurrence, there will be no effect on the Baseline usage or Usage Avoidance. The bill that was cast out was a December bill. When a post-retrofit December comes around, the software will collect up the number of bill days, and the number of HDDs associated with the post-retrofit December billing period, and will insert them into the fit line equation, just like any other bill period. The resulting number will be the Baseline usage. The software will treat December just like any other month. So, in essence, by casting out a bill, the only thing you are doing is ignoring it when determining the Baseline.

Some contractors will get a little out of hand when tuning, and will deselect more bills than is necessary. In general, you should try to avoid deselecting bills whenever possible. Since you are trying to create a model (the fit line equation) of pre-retrofit usage, how can you do that if you are using very few pre-retrofit bills? How accurate would that be? Believe it or not, on more than one occasion I have seen meters tuned like the one in Figure 14-14 below. Three bills do not represent the entire

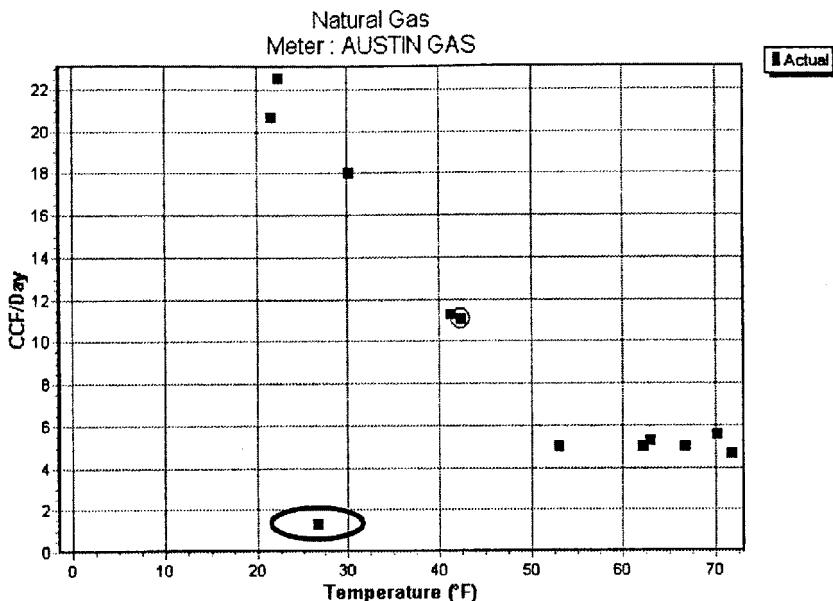


Figure 14-11. A set of bills with an outlier (circled).

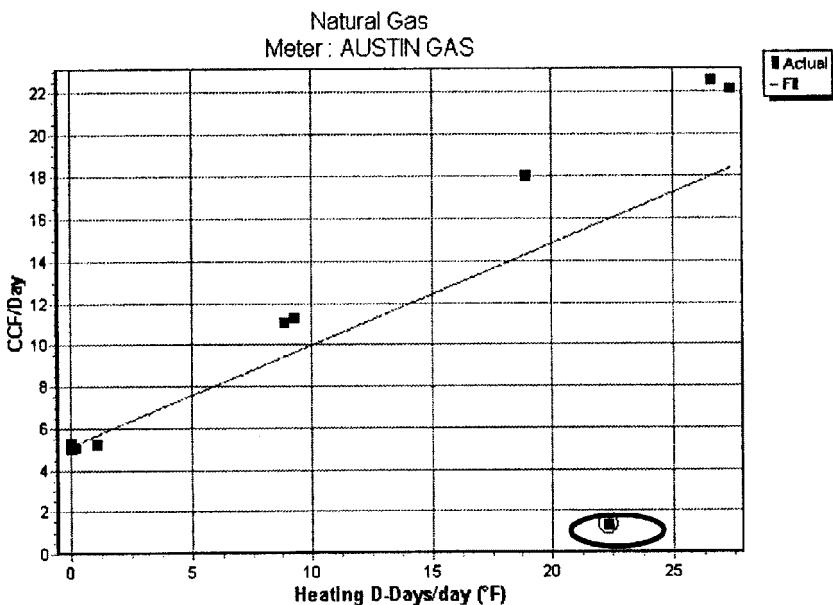


Figure 14-12. The outlier drags the fit line down so that the fit line does not approximate any of the heating bills well.

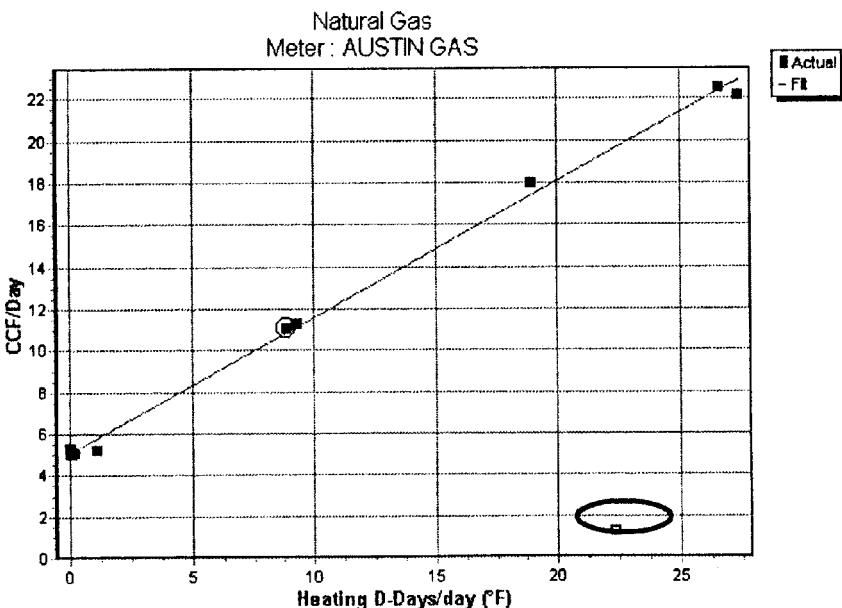


Figure 14-13. After deselecting the outlier, the meter tunes well.

year! See how far the deselected bills are from the fit line! There are two main reasons why a contractor would deselect too many bills: either he didn't know enough not to, or he was trying to manipulate the savings numbers. Just by deselecting a low bill, a contractor can raise the fit line, and thereby increase the Baseline, and thus increase Cost Avoidance. I have seen this happen. Sometimes they deselect bills so that they can get the R^2 value to be nearly perfect. (We will talk about R^2 soon.) In this case, deselecting bills to get a perfect fit is not done out of malice, but merely from inexperience, and depending upon which bills are deselected, this may benefit either the contractor or the customer.

I don't want to mislead you. If you find that the contractor has deselected several bills, then ask why, and he may have a perfectly good answer. There are times when it is wise to deselect several bills. If you are tuning a school, and there is a summer break, and a winter break, the bills covering those months may not tune well. If the school is shut down during these periods, you wouldn't expect the school to use the same energy as it would when open. Some contractors will deselect these bills from the tuning, because they would adversely affect the quality of the fit line if selected. They then would "bill match" these deselected billing

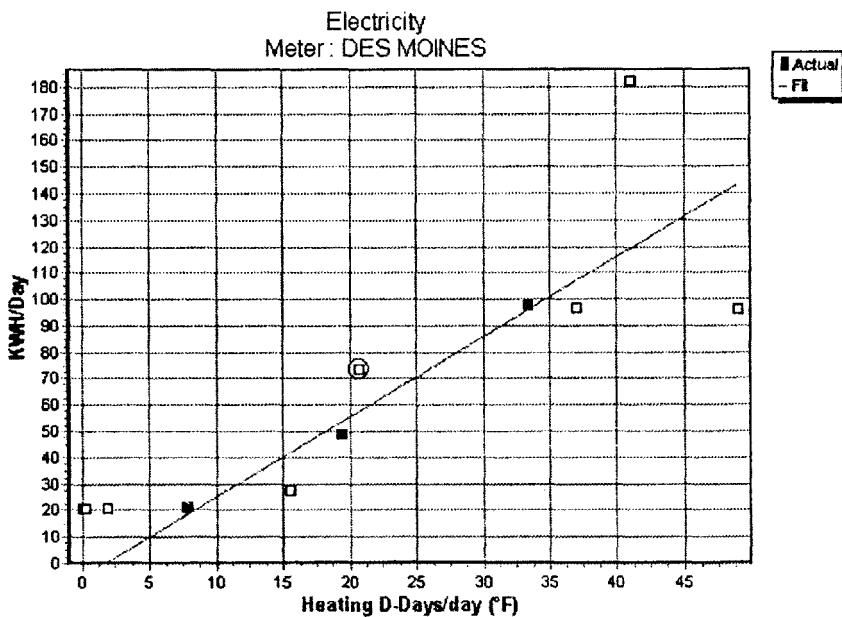


Figure 14-14. An example of poor tuning. You cannot use 3 bills to represent a full year of usage.

periods. In a very gross sense, this means, they use Bill Comparison for the school break periods and then use weather regression for the other periods.

Tuning the Meter

Tuning is actually pretty simple. With good UBA software, you only need to determine the following:

- Which bills to tune
- Whether the meter will tune to HDDs, CDDs, and/or some other variable
- Whether any bills should be deselected from the tuning
- The balance point(s) of the meter

Once these determinations are made, the program will find the best-fit line through the bill points, and will determine the fit line equa-

tion. That is nearly all there is to it. It makes you wonder, if it is so simple, why did I make you wade through so many pages to figure this out?

Fine Tuning the Regression

Once the performance contractor has made initial estimates of the balance points and determined whether the meter is heating and/or cooling, he then will fine-tune the regression. The contractor will adjust the balance points a few degrees in either direction from the initial balance point estimates, relying upon statistical criteria and some common sense to determine the best tuning. There are several rules of thumb which should be followed when perfecting a tuning, but they sometimes contradict each other and the contractor will then need to use his best judgment. I have listed the tuning equation (for reference) and the criteria in Table 14-5.

$$\begin{aligned}
 \text{Baseline} &= \text{Coef}_{\text{CDD}} * N_{\text{CDD}} & \text{Constant} & * N_{\text{days}} \\
 \text{Usage} & \\
 \text{kWh} &= 74.16 \text{ kWh/CDD} * N_{\text{CDD}} + 5619.3 * N_{\text{days}} \\
 &&& \text{kWh/Day} \\
 y &= M * x + b
 \end{aligned}$$

The ASHRAE Guideline 14P details two other statistical guidelines, the CVRMSE and the Net Mean Bias which should be considered, but presently, as the Guideline is not yet widely available, it is not used by most practitioners. When the Guideline becomes widely available, contractors will likely consider these parameters as well.

Finding the Best Tuning (There Isn't One)

You can put 20 M&V experts in a room, and give them a set of bills to tune, and there would likely be at least 10 different tunings when they are done. Not only that, they would all likely say they have a correct tuning and a good argument to back it up. Tuning is an art. As long as the statistical criteria are met and the tuning is explainable in words, then it is probably fine. If you are suspicious of your performance contractor, don't worry. As long as he followed the rules, the tuning should be fine. If you are a performance contractor, just stay within the guidelines and you will be ok.

Table 14-5 Listing of Criteria Used to Determine the Best Tuning

Criteria	Notes
The baseload constant (part of the b term) should not be negative	If the baseload coefficient was negative, how would you explain it? The meter uses negative electricity every day? This may be acceptable if the meter serves a cogeneration plant, fuel cells, or some other electricity producing device that occasionally sells power back to the utility.
The weather coefficient (the m term) should not be negative	Rather than have a negative CDD coefficient, it is more explainable to have a positive HDD coefficient.
The R^2 value should be high	Most contractors will try to maximize the R^2 value, which can range between 0 and 1. The R^2 value is an indicator of how well the best-fit line fits the bill points. An R^2 value > 0.75 is considered acceptable in our industry.
The lowest bills in the Base Year should match the baseload coefficient	Usually, for single variable tunings, the 2 or 3 bills with the lowest consumption in the base year have 0 degree days associated with them. This means these bills are pure base-load. As a result, their average amounts should match the b term in the regression equation. To use this strategy, the average kWh/day of these 2 or 3 lowest bills should match the baseload constant (part of the b term).
The selected balance point should be reasonable and explainable.	You can follow all the rules and get a good fit and an unreasonable balance point.
The T statistics for each independent variable should be > 2	The T statistics tell us whether an independent variable, such as CDDs or number of school days, should be used in the regression. If an independent variables' T statistic is greater than 2, or less than -2 then the variable can be used.

Measuring Error for the Tunings

We tuned for the bills shown in Figure 14-4 to get the fit line equation below:

$$y = M * x + b$$

$$\text{kWh} = 71.3397 * N_{\text{CDD}} + 5539.56 * N_{\text{days}}$$

$$\text{kWh/CDD} \qquad \qquad \qquad \text{kWh/Day}$$

If we plug in data (CDDs and Number of Days) from one of these bills back into the fit line equation, then we should get the original bill amount right? Let's try the January 5th bill:

$$y = M * x + b$$

$$\text{kWh} = 71.3397 * N_{\text{CDD}} + 5539.56 * N_{\text{days}}$$

$$\text{kWh/CDD} \qquad \qquad \qquad \text{kWh/Day}$$

$$= 71.3397 * 0 + 5539.56 * 32$$

$$\text{kWh/CDD} \qquad \qquad \qquad \text{kWh/Day}$$

$$= 0 + 177265.92 \text{ kWh}$$

$$= 177,265.92 \text{ kWh}$$

The original bill for January 5th was 184,500, so we can see that the calculated Baseline does not match the actual bill during the Base Year. There is an error, or, as the last column of Figure 14-15 shows, a deviation of 3.9%.

The reason for the error is that the fit line did not land exactly on all the bills. The difference between the (pre-retrofit) January 5th bill and the fit line is the 3.9%.

Figure 14-15 presents Base Year period utility bill consumption (in the Reading column), calculated Baseline (in the Baseline column), and percent error (in the Deviation column). Typically, each month would have a small error. ASHRAE Guideline 14P suggests that contractors try to minimize the average of these monthly errors. The CVRMSE, Coefficient of Variation of the Root Mean Square Error, is a way to quantify these monthly errors.

From	To	# Days	Reading	Incl?	HtgDD	ClgDD	Multi-plier	Offset	Baseline	Deviation
06/06/97	07/07/97	32	227,000	<input checked="" type="checkbox"/>	6	795	1.0	0	233,945	3.1%
07/08/97	08/05/97	29	230,000	<input checked="" type="checkbox"/>	0	915	1.0	0	225,888	-1.8%
08/06/97	09/04/97	30	21e.500	<input checked="" type="checkbox"/>	12	731	1.0	0	218,301	-0.1%
09/05/97	10/06/97	32	228,000	<input checked="" type="checkbox"/>	49	649	1.0	0	223,530	-2.0%
10/07/97	11/04/97	29	109,000	<input checked="" type="checkbox"/>	503	126	1.0	0	169,600	0.4%
11/05/97	12/04/97	30	1 09,000	<input checked="" type="checkbox"/>	932	2	1.0	0	166,294	-1.6%
12/05/97	01/05/98	32	184,500	<input checked="" type="checkbox"/>	1,118	0	1.0	0	177,266	-3.9%
01/06/98	02/05/98	31	173.500	<input checked="" type="checkbox"/>	1,249	0	1.0	0	171,726	-1.0%
02/06/98	03/04/98	27	141,500	<input checked="" type="checkbox"/>	756	7	1.0	0	150,032	6.0%
03/05/98	04/06/98	33	188,000	<input checked="" type="checkbox"/>	995	49	1.0	0	186,266	-0.9%
04/07/98	05/05/98	29	171,500	<input checked="" type="checkbox"/>	332	185	1.0	0	173,845	1.4%
05/06/98	06/04/98	30	203.500	<input checked="" type="checkbox"/>	70	557	1.0	0	205,887	1.2%
Total or Average		364	2,304,000		6,019	4,012	1.0		2,302,580	-0.1%±2.4%

Figure 14-15. In this listing of bills tuned, "Reading" represents the actual bill amount, and "Baseline" is the bill amount calculated using the tuning equation, and "Deviation" is the percent error of the Baseline.

For the entire Base Year period, if you compare the sum of the utility bill consumption with the sum of calculated Baseline (look in the Total or Average row), again there will be an error. This error is called the Net Mean Bias Error. The Net Mean Bias Error represents the total error of the fit line. ASHRAE Guideline 14P also has guidelines for the Net Mean Bias Error.

There are several criteria to help the contractor determine whether a tuning is acceptable. These criteria have been evolving (that is, changing) over the last few years. The latest set can be found in ASHRAE Guideline 14P. I have listed criteria from ASHRAE Guideline 14P, as well as other criteria, in Table 14-6.

According to ASHRAE Guideline 14P, if a tuning meets the criteria listed in Table 14-6, then the regression is considered acceptable.

Keep in mind that as of this writing no UBA software displays the Mean Bias Error or the CVRMSE in the areas of the program where weather regression is performed. This will change soon with the coming new release of Metrix™ 4.0. In addition, although the ASHRAE Guideline 14P has been released as of this writing, M&V professionals are just now starting to become aware of it. Both of these factors may help account for the fact that most contractors have not been paying attention to these two measures.

OTHER INDEPENDENT VARIABLES

Some meters are not weather-sensitive. For example an electricity meter that supplies a lighting panel in a factory has no correlation to weather at all. If the factory operates between 1 and 3 shifts depending upon orders received, then it is likely that the lighting meter could correlate to number of man-hours worked. If the meter cannot tune to weather, then the best option is to determine which independent variable the meter will tune to, gather the appropriate information and tune to those data. Sometimes it is not known which independent variable is driving usage, or there is not enough time or money to collect data for the independent variable. In this case, no regression is performed at all.

Table 14-6 Listing of Criteria Used to Determine Whether a Tuning is Acceptable

Criteria	GCP 14P Guideline	Description
R ²	R ² > 0.75	R ² represents the quality of the fit. The closer the line to the bill points in the graph, the higher the R ² value. The ASHRAE Guideline 14P does not mention the R ² value, however FEMP Guidelines do, and it is standard practice to use the R ² value at this time.
T statistic	For each independent variables used: T statistic > 2 or T statistic < -2	The T statistic demonstrates the meaningfulness of each independent variable to the regression. The ASHRAE Guideline 14P is more complex than what I present here, however, this will suffice.
Net Mean Bias Error	NMBE < 0.005	This is the total error, expressed as a percentage, when comparing the regression to the actual bills during the base year.
CVRMSE	CVRMSE < 25 for energy, CVRMSE < 35 for demand	The CVRMSE (Coefficient of Variation of the Root Mean Square of the Error) can be generalized to represent the average magnitude of error for each bill. If half the baseline amounts were high by 10% and half the baseline amounts were low by 10%, and the Net Mean Bias Error was exactly 0%, the CVRMSE would equal about 10%.

WHAT DO YOU DO WHEN THERE IS NO CORRELATION TO WEATHER?

On some meters, there is demonstrated weather sensitivity. As it gets hotter, there is more electricity usage, but the fit line may not land close enough to the bill points, and as a result, the R^2 value may never rise above 0.75. In this case, the same procedure is followed: determine if there are other independent variables the meter can tune to, and if none can be found, then do not perform a regression at all. In place of weather regression, Utility Bill Comparison is then used. This is also called “Bill Matching.”

DOCUMENTING YOUR TUNINGS

Performance Contracts utilizing UBA should include documentation of bill parameters and tuning statistics. It is important to document these Baseline parameters so that there is no confusion or disagreement during the term of the contract. The M&V plan may be clear and acceptable to all parties at the time of contract signing, but, all too often, the parties who negotiated and wrote the contract are not the same people who years later are left to track and oversee cost avoidance calculations. It is the second and following generations who must be considered when creating M&V documentation. You should never expect these succeeding generations to act rationally. Rather, the contract should be written to withstand assaults from either side. The various M&V guidelines list what documentation is necessary for a successful contract. Fortunately, good M&V software has all the documentation you need about weather regression, all rolled up into one report, the Meter Tuning Contract, presented in Figure 14-16.

APPLYING COSTS TO YOUR SAVINGS CALCULATIONS

There are several ways to apply costs to savings calculations. The simplest way is to use some agreed upon rate, say \$0.10/kWh for all kWh saved. Some performance contracts are written this way, but more often you will see contracts that use either a blended rate or the current utility rate.

(Editor’s Note: Readers should be sure to read the Appendix entitled “Valuing Energy Savings” for further discussion and examples regarding this issue.)

Meter Tuning Contract

Project: Tuning Meter: LINCOLN 3				Site: Lincoln Unit: Qty On-pk (kWh)			Area: LINCOLN			
From	To	Days	Reading	Incl?	HtgDD	ClgDD	Multiplier	Off set	Baseline	Deviation
06/06/97	07/07/97	32	227,000	<input checked="" type="checkbox"/>	5	795	1.0	0	233,945	3.1%
07/08/97	08/05/97	29	230,000	<input checked="" type="checkbox"/>	0	915	1.0	0	225,888	-1.8%
08/06/97	09/04/97	30	218,600	<input checked="" type="checkbox"/>	12	731	1.0	0	218,301	-0.1%
09/05/97	10/06/97	32	228,000	<input checked="" type="checkbox"/>	49	649	1.0	0	223,530	-2.0%
10/07/97	11/04/97	29	169,000	<input checked="" type="checkbox"/>	503	128	1.0	0	169,600	0.4%
11/05/97	12/04/97	30	169,000	<input checked="" type="checkbox"/>	932	2	1.0	0	166,294	-1.6%
12/05/97	01/05/98	32	184,500	<input checked="" type="checkbox"/>	1,118	0	1.0	0	177,266	-3.0%
01/06/98	02/05/98	31	173,500	<input checked="" type="checkbox"/>	1,249	0	1.0	0	171,726	-1.0%
02/06/98	03/04/98	27	141,500	<input checked="" type="checkbox"/>	755	7	1.0	0	150,032	6.0%
03/05/98	04/06/98	33	188,000	<input checked="" type="checkbox"/>	995	49	1.0	0	186,266	-0.9%
04/07/98	05/05/98	29	171,500	<input checked="" type="checkbox"/>	332	185	1.0	0	173,845	1.4%
05/06/98	06/04/98	30	203,500	<input checked="" type="checkbox"/>	70	657	1.0	0	205,887	1.2%
Total or Average		394	2,304,000		61819	4,012	1.0	0	2,302,580	-0.1%:±2.4%

Below is the equation used to calculate the Baseline values for the tuning period and all future periods:

$$\text{Baseline (kWh)} = 5,539.56 \times \# \text{ Days} + 71.3397 \times \text{ClgDD}$$

- This Baseline Equation has a Net Mean Bias of -0.1% and a Monthly Mean Error of ±2.4%. The underlying regression has a $R^2=0.968$
- Baseline Costs are calculated using Rate Tariff documented in separate attachment

Explanations and Assumptions:

- (empty checkbox) under 'Incl?' indicates that the bill is excluded from the regression. However the Base Equation is always applied for all billing periods, even those excluded from the regression.
- HtgDD=Heating Degree-Days calculated for LINCOLN, NE for a 65.0°F balance point.
- ClgDD=Cooling Degree-Days calculated for LINCOLN, NE for a 48.0°F balance point. Periods under 0.0°F-days/day are excluded from regression. but are still used in applying the Baseline Equation.

Figure 14-16. The Tuning Contract Documents Baseline Parameters.

Typically the same rate is applied for both Baseline and current usage, whether it is a stipulated, blended or actual rate. The rate applied to both Baseline and current usage is usually the current rate, unless otherwise noted in the contract.

The Greater of Current Rate or Rate at Time of Contract Signing

Whether the contracts apply blended rates or actual rates, many contracts will stipulate that the rate to use is either the rate at the time of the signing of the contract or the current rate, whichever is greater. The skeptical reader may see this as an example of performance contracting companies biasing the contract in their favor, but you have to see it from the performance contractors' perspective as well. They don't want to lose their shirts. Suppose you had a performance contract in which the current rate was going to be used. What happens if the rate stays the same? Nothing. What happens if the rate drops? Suppose the contractor guaranteed and did save the customer 1,000,000 kWh each month. If the rate was \$0.25/kWh when the contract was signed, and the rate then dropped to \$0.20 kWh, then the customer is saving \$50,000 less per month with this new rate. Even though the performance contractor saved the customer the guaranteed 1,000,000 kWh per month, the contract may still have to make up that \$50,000 per month in extra savings, or write a check for it. Utility rates are beyond the contractor's control, and without this provision, decreases in rates could ruin a performance contracting company. That's why this provision is often added to the contracts.

Blended Rates vs. Actual Rates

If actual utility rates are used, this could lead to some confusion, because in many areas, utility rates can be extremely difficult to understand. (Sometimes it seems that the rates guys make the rates as complex as possible out of malice.) Once the contractor understands the rate, he might have to explain it to the customer, and sometimes, this also can be difficult. Simplicity is always worth striving for.

Blended rates are a simple way to handle costs. Suppose for a billing period that Baseline usage was 10,000 kWh and the current usage was 8000 kWh, and current total cost was \$800.00. It doesn't matter how complex the rate was, we just look at total cost. One way of applying blended rates would be to determine the average \$/kWh of the current bill. In this case, we have $\$800/8000 \text{ kWh} = \$0.10/\text{kWh}$. So, the blended

rate (\$0.10/kWh) would be applied to both the Baseline usage, and the current usage.

	kWh	\$/kWh	\$
Baseline	10,000	\$0.10	\$1000
Current	8,000	\$0.10	\$800
Avoidance	2,000	\$0.10	\$200

This may seem the best solution, and some performance contracting companies will use blended rates as it does simplify what could be unnecessary complexity. However there could be some problems associated with blended rates. I will give two examples.

Suppose the performance contractor installed a thermal energy storage (TES) system on your premises. TES systems run the chillers at night, when electricity is cheap, and store the cooling energy as either ice or chilled water in large storage containers. Then during the day when electricity is expensive, the chillers either don't run at all, or run much less than they normally would. This strategy saves money, but it doesn't save energy. In fact it uses more energy, as some of the cooling energy stored in the storage container is lost through the walls of the container, and the extra pumping required may consume extra energy. If you applied a blended rate to the TES system you might see for a bill:

	kWh	\$/kWh	\$
Baseline	10,000	\$0.10	\$1000
Current	10,500	\$0.10	\$1050
Avoidance	-500	\$0.10	-\$50

Even though you saved costs, if you used blended rates, you might not see the Cost Avoidance that really occurred.

Suppose the performance contractor installed a new energy efficient boiler and boiler controls in a school that is mostly vacant in the summer. Suppose the current gas rate was:

Charge	Rate
Monthly Charge	\$25
Usage Charge	\$1.30/therm

For January, which had maybe 100 therms usage, the current bill would be

Charge	Usage	Rate	Cost
Monthly Charge	N/A	\$25	\$25
Usage Charge	100 therms	\$1.30/therm	\$130
Total Bill			\$155
Blended Rate \$/therm = \$155/100 therms = \$1.55/therm			

If our Baseline usage for January was 120 therms, then savings would be calculated using the blended rate as:

	therms	\$/therm	\$
Baseline	120	\$1.55	\$186
Current	100	\$1.55	\$155
Avoidance	20	\$1.55	\$31

That seems to work well. Now try July, in which the current bill might have had 1 therm usage, the bill would be:

Charge	Usage	Rate	Cost
Monthly Charge	1	\$25	\$25
Usage Charge	1	\$1.30/therm	\$1.30
Total Bill			\$26.30
Blended Rate \$/therm = \$26.30/1 therms = \$26.30/therm			

And supposed Baseline usage in July was 4 therms

	therms	\$/therm	\$
Baseline	4	\$26.30	\$105.2
Current	1	\$26.30	\$26.30
Avoidance	3	\$26.30	\$78.90

The blended rate calculation told us that the customer saved \$78.90, whereas the actual rate calculation would have told us that the customer saved 3 therms * \$1.30 / therm = \$3.90. I see this problem often.

Although blended rates can simplify the calculations, they can really muck up the savings numbers when some months have little usage. Blended rates can also cause problems for demand reduction strategies, such as the TES example discussed above.

Applying Different Rates to Baseline and Current Quantities

As mentioned before, if the contract is using actual rates, then the same rate is usually applied to both Baseline and current usage and demand. There are exceptions of course. If the contractor was able to transfer the customer's meters to a different rate, then the rate to apply to baseline quantities would be the customer's old rate, and the rate to apply to current quantities would be the new rate. The easy way to understand what rate should be used for Baseline is to answer the question: "what would the rate have been if there was no performance contract?" The answer would likely be the rate that should be applied to the Baseline.

Whether the contract has stipulated rates, blended rates, or modeled rates, good M&V software can handle all of these situations.

BASELINE MODIFICATIONS AND RISK

One of the drawbacks of UBA for performance contractors is the added risk they are taking on due to unforeseen changes in facility energy usage patterns. If a customer adds to his electricity consumption

through renovations, schedule changes, new equipment, or changes to building control strategies, usage and costs can rise, and thus cost avoidance could plummet. As a result, performance contracts often state that the customer must inform the contractor about significant changes to the building's energy usage patterns. The contractor would then add a baseline modification (also called baseline adjustment) that accounts for this additional usage.

To properly handle the baseline adjustments that will eventually occur, performance contracts should document as much as possible building operating conditions during the Base Year period. This includes conditioned square feet, operation and occupancy schedules, control set points, a listing of significant energy consuming equipment in the building, etc. Generally a detailed energy audit will provide this information. Then, if there is a change in some energy consuming behavior, there are documented pre-retrofit conditions for comparison. Performance contracts should also have a section which explains how baseline modifications will be calculated. Of course the contract will not be able to predict what types of building changes will occur, and will likely not cover all possibilities.

Baseline Modifications in Practice

Suppose you installed a lighting retrofit, and it looked as if you were saving the energy you expected to save, and then the building added a new wing. Now, as shown in Figure 14-17, the extra energy consumed by the new wing will make your savings disappear.

To correct for this, you add a Baseline Modification, which allows you to enter the increase in usage associated with the new wing. This increase is then added to the Baseline amount, as Figure 14-18 shows.

The next question is "How do you add the adjustment to the Baseline?" If there are no Baseline adjustments, then the Baseline Equation is the same as the fit line equation. However, if there are adjustments, then the Baseline Equation has a couple of extra terms. Suppose we start with a simple fit line equation:

$$\text{Baseline kWh} = \text{Constant} * N_{\text{days}} + \text{Coef}_{\text{CDD}} * N_{\text{CDD}}$$

We then add the adjustment terms...

$$\text{Baseline kWh} = (\text{Constant} * N_{\text{days}} + \text{Coef}_{\text{CDD}} * N_{\text{CDD}}) * \text{Multiplier} + \text{Offset}$$

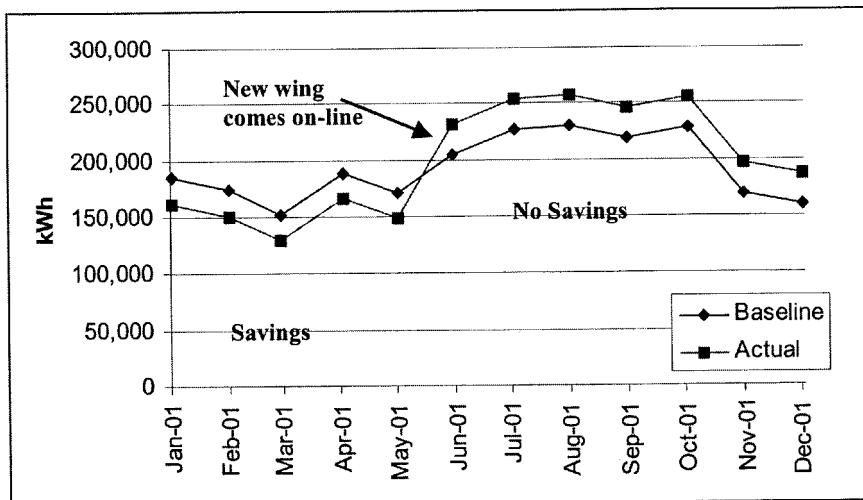


Figure 14-17. The additional usage from the new wing that came on-line in June 2001 erased the savings from ECM's previously installed.

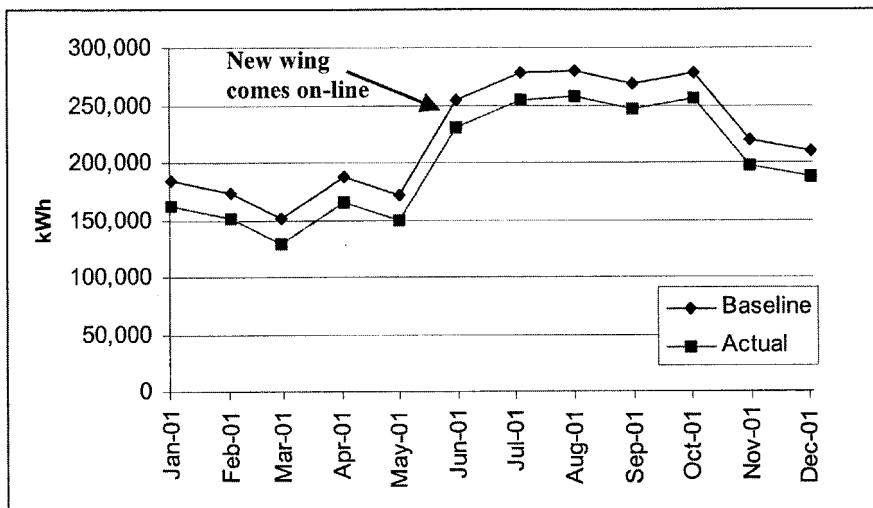


Figure 14-18. In order to account for the additional usage from the new wing, an adjustment is added to baseline.

The Multiplier and Offset terms are used to add % or absolute changes to the Baseline. For example, if you wanted to add 20% to Baseline usage for the new wing, the multiplier would be 1.2 and the Offset would be 0. If you wanted to add 50,000 kWh to the Baseline for the new wing, then the Multiplier would be 1 and the Offset would be 50,000 kWh.

Baseline adjustments, so far, may appear very simple. What I have neglected to mention is how the performance contractor determines how much extra energy the new wing is using. Suppose the new wing is not sub-metered. How will he know how much extra energy is being used by the new wing? Suppose the facilities staff overrode the chilled water setpoint, leading to increased energy usage, and the performance contractor wants to make a baseline adjustment. How will he know how much to adjust? This is the hard part of UBA.

There are several ways to determine these numbers. Each way will give a different number, and therefore lead to a different savings result. We will get into this in more detail in the next section.

For now, the best ways to calculate baseline adjustments are to:

- Use an existing building model (if one does exist) to calculate the increase/decrease in usage
- For new wings, use kWh/Sq-Ft from the existing building and just apply that ratio to the new wing's area.
- Use spreadsheets and engineering equations to determine the baseline adjustment. This can be done in simple cases like more computers, new MRI machine, new exhaust fans, etc.

THE DEATH STRUGGLE

I believe that if you treat people fairly, they will become assets for you. This same philosophy should apply to the performance contracting relationship. It is supposed to be a partnership for mutual benefit, not a death struggle. When both parties act honestly, both parties will likely benefit. However, sometimes this is not the case, and of course, these are the contracts we all hear about.

If you are planning on becoming involved in a performance con-

tract that uses UBA, and want to remain vigilant against deception of any kind, the best place to look is in the calculation of baseline modifications. If you are a performance contractor, then you already know, baseline modifications is the gray area of calculating savings, where things can get out of hand.

The IPMVP, FEMP Guidelines, ASHRAE Guideline 14P and all the other expert advice are very helpful in defining acceptable UBA procedures. But when it comes to calculating baseline modifications, they don't offer much help. You can't blame them either. The subject is too complex. There are too many possible situations that can arise, each of which requires a unique solution. Since expert guidelines don't abound, modifications can be a gray area where there is no known right answer, and accordingly this is where practitioners can stumble into morally treacherous territory.

Many performance contractors will model the customer's building as part of the initial energy study. If there is a building model available, using the model to calculate baseline adjustments is certainly the simplest and most impartial method. For example, if the facility manager of a contracted building has lowered the chilled water set point and extended some air handler schedules so that they no longer match the documented Base Year conditions, then the contractor will want to make a baseline adjustment. The simple way to determine the size of the baseline adjustment is to make a few simple changes to the existing building model's input file, and thereby calculate reasonable estimates of the change in energy usage. But what about cases where there is no building model. Now what is the performance contractor going to do?

For many situations like the one described above, there are no clear-cut methods to estimate baseline adjustments. If the performance contractor estimates (guesses) high by 10%, he is cheating the customer. If he estimates (guesses) low by 10%, he is cheating his company. It is a fine line to walk when calculating adjustments, because any error on the contractor's part will lead to someone getting cheated. Try living with that.

What is even worse is that, for many situations, there may be more than one method that can be used to calculate the baseline adjustment. Suppose the contractor tries two different methods just to be safe. One method returns a higher baseline adjustment than the other. Now which adjustment does he choose: the higher adjustment or the lower adjustment? Which is correct? Couldn't they both be high? Or

both low? Only God would know. So, whom is the contractor cheating? Here is an example. The hospital adds a new wing. They don't add a submeter (which would have been the simple solution), and the new wing draws power from the existing electricity meter. How are you going to calculate the baseline modification? Do you think you will be within 10%? I doubt it.

It goes both ways, though. When I was a performance contractor, I had a customer who wouldn't tell me about changes to his facility, because he saw the performance contract as a game, and to him, to win meant to get the performance contracting company to write checks. On the other hand, having taught hundreds of performance contractors, I have met some who sounded as if they too were playing a game wherein winning meant doing anything in order to avoid writing a shortfall check. Honesty wasn't a concern at all.

REPORTING YOUR RESULTS

One of the biggest problems with weather regression methods is explaining it. Although it isn't that difficult a concept, it can be difficult to practice, and thus difficult to convey what was done. Fortunately, good M&V software does offer some useful aids in explaining how you arrived at your savings numbers. One of the reports available in Metrix is the verification detail report, shown in Figure 14-19. The verification detail shows step-by-step how the baseline energy is calculated.

When I was just a novice energy analyst, I learned about explaining M&V to my customers. I was supposed to present the savings results for the past year at a board meeting. At the time, I thought that most important thing was to have everything backed up, in case anyone wanted to go deeper into the numbers to see where they came from. I handed out copies of everything I could think of, and then gave a talk that explained the regression and how savings were calculated. I thought I gave a great presentation. Apparently I hadn't. I was later contacted by the facility manager who told me that none of them understood what I was talking about. Not only that, they didn't want to see me again. I was to instead report savings to him in a "straightforward" manner. Explaining weather regression to customers is not always easy, but somehow it gets done all the time.

Figure 14-19. This verification report details step-by-step how the baseline energy usage was calculated. In this example, there were 29 days and 3.5 CDDs, which were inserted into the baseline equation.

End Date: 03/06/97

Meter: LINCOLN 3	Type: Qty On-pk	Period: 29 days ending 03/06/97		
Variable(s): 5,539.56	$\times 29.0$	= 160,647.24 kWh		
Constant	# Days			
Cooling: 71.34	$\times 3.5$	= 249.69		
Coefficient	DegreeDays			
		LINCOLN, NE		
		Weather Name		
		Preliminary Baseline		
Modification(s): 1,0000	$\times 160,896.93$	+0.00 = 160,896.93 kWh		
Non-Temperature-Sensitive Consumption	Temperature-Sensitive Consumption	Baseline Consumption		
Actual:	148,500.00 kWh	Actual		
Savings Calculations:				
Actual Savings:	160,896.93 -- Baseline	148,500.00 = Actual	12,396.93 kWh	Actual Savings
Target Savings:	160,896.93 -- Baseline	160,896.93 = Target	0.00 kWh	Target Savings
	Actual Savings - Target Savings =		12,396.93 kWh	Variance

GLOSSARY

Table 14-6 Glossary of Terminology Used in UBA Software

Balance Point	The cooling balance point is the temperature at which the building starts cooling. The heating balance point is the temperature at which the building starts heating. This is a crude but effective definition. CDDs and HDDs are calculated using the balance point.
Baseline	Baseline is a confusing term because it appears to have many meanings in the energy industry. For this discussion, “Baseline” represents “how much energy would have been used during the Pre-Retrofit period, given today’s conditions,” where “today’s conditions,” for the most part, means weather and number of billing days.
Baseload	The energy used that has nothing to do with weather or any other independent variable in the regression. Baseload energy is usually composed of lights and computers and 24/7 fans and pumps.
Baseline Equation	<p>The Fit Line, which was created when a regression was performed, has an equation, which is called the “Fit Line Equation.” The Baseline Equation is the same as the “Fit Line Equation, except it can also have Baseline adjustments tacked onto it.</p> <p>$\text{Baseline Equation} = \text{Fit Line Equation} +/- \text{Baseline Adjustments}$</p>
Base Year	The pre-retrofit period whose bills are used to perform the weather regression. Base Year bills represent what energy usage used to be before the ECM’s were introduced.
Cooling Degree Day (CDD)	CDDs are a way to measure how much cooling is required in some period of time. A large number of CDDs signifies that the building required a large amount

of cooling. Zero CDDs signifies that the building did not require any cooling.

In case you are interested, CDDs for each day are calculated as follows:

$$\text{CDD} = (T_{\text{mean}} - T_{\text{Balance Point}}) * N_{\text{day}} +$$

Where T_{Mean} is the average of the high and low temperature for a day, and $N_{\text{day}} = 1$, and CDD must always be positive.

For Utility Bill Analysis, CDDs are calculated separately for each day and then summed together into billing periods.

Cost Avoidance	Almost the same as Cost Savings, but different. Cost Avoidance is the difference between how much utility usage would have cost had no ECM's been installed, and how much utility usage actually did cost after ECM's have been installed.
ECM	Energy Conservation Measure. This term is widely used to represent any energy efficiency project that will reduce energy expenditures.
Energy Avoidance	Almost the same as Energy Savings, but different. Energy Avoidance is the difference between how much energy would have been used had no ECM's been installed, and how much energy was used after ECM's have been installed.
Fit Line	Fit Line is another term for "best-fit" line, or the line that comes closest to all the points in the graph.
Fit Line Equation	Every line can be defined by an equation, such as $y = mx + b$. The Fit Line Equation is the equation for the Fit Line.

Heating Degree Day (HDD) HDDs are a way to measure how much heating is required in some period of time. A large number of HDDs signifies that the building required a large amount of heating. Zero HDDs signifies that the building did not require any heating.

In case you are interested, HDDs for each day are calculated as follows:

$$\text{HDD} = (T_{\text{Balance Point}} - T_{\text{Mean}}) * N_{\text{day}} +$$

Where T_{Mean} is the average of the high and low temperature for a day, and $N_{\text{day}} = 1$, and HDD must always be positive.

For Utility Bill Analysis, HDDs are calculated separately for each day and then summed together into billing periods.

Non-Temperature-Sensitive Usage The energy used that is not related to weather. This would include computers, lights, pumps, kitchen equipment, etc.

Regression Regression is a statistical operation, which graphically can be described as drawing a straight trend line (or “best-fit” line) as close to all the points in a graph as possible. The “best-fit” line, or regression, then is said to represent the points in the graph. Also called Tuning.

Savings The reduction in the quantity (of energy or water) that can be discerned from utility bills.

Tuning Tuning is the process of performing a regression. A Tuning Graph is a graph that shows the points and the “best-fit” line. Tuning and Regressing are synonyms (as verbs). Tuning and Regression are synonyms (as nouns).

Temperature-Sensitive Usage The energy used that is related to weather. This would mean air-conditioning equipment, chillers, cooling towers, boilers, hot water pumps, etc.

Chapter 15

The Impact of Operations And Maintenance on ESCo Project Results

Louis J. Ronsivalli, VESTAR

INTRODUCTION

Creative thinking during the early to mid 1980s yielded new opportunities to provide much-needed capital improvements in aging public sector buildings as well as many private-sector plants and facilities. Some of the new contracting methods conceptually provided an economically sound approach to managing the 'health' of building systems. Programs were developed to shift more of the risk to contracting companies designing projects to achieve aggressive operating cost avoidance and to improve building system efficiencies. Many commercial, high-rise and institutional buildings suffered from what we might commonly term 'deferred maintenance' symptoms. High-rise buildings of the late 1960s and early to mid 1970s, built with designs focused on comfort and aesthetics, were built with some of the least efficient HVAC systems ever to appear on drafting tables. The HVAC systems of this era featured comfort, "power" with large, central, high-pressure, high-horsepower equipment, liberal use of conditioned outside air, re-heating of pre-cooled (air-conditioned) supply air, and mixing of air from hot 'decks' (supply air ducts) with air from cold 'decks,' in what are known as constant-volume, dual-duct systems. Older, inefficient building systems were designed to operate similarly to maintaining the automobile's ventilating fan on 'high' at all times and adjusting the temperature lever to maintain comfort. These systems were operating cost disasters, pushing utility bills as high as three times greater than those

for buildings built in prior years.

National concerns regarding energy use had increased dramatically during the oil embargo of the 1970s, and the public sector was looking for ways to respond to the challenges. The HVAC and electrical equipment industries were also beginning to respond. Over the next several years, control systems would become cost-effective and technology advances in all building system components would become more commonplace. Designs would soon emphasize higher operating efficiencies.

When the Commonwealth of Massachusetts introduced its 'Pilot Program for Shared Savings' following a comprehensive study by its Division of Capital Planning and Operations in the early 1980s, a new era in conservation contracting opportunities had dawned. In other parts of the country, similar programs were being developed and championed by public sector planning officials. But retrofitting HVAC and electrical systems raised post construction issues about maintaining and operating building systems for occupant comfort, reliability, safety and efficiency. The integration of building retrofit projects with multi-year maintenance and operations agreements programs became known as 'Energy Services' (now more specifically known as Performance Contracting) and companies providing these services, would be known as Energy Services Companies, or 'ESCO's.'

This chapter provides an overview of the impact that maintenance and operations practices have had on the effectiveness of energy conservation measures and performance contracting. We will review many of the concerns voiced during the early days of performance-based contracting, and discuss some of the lessons learned. Let's begin with some of the basic issues involved in developing a successful program.

The Value Impact

Early in the implementation phase of 'first generation' energy services projects, it became evident that the competence with which building systems had been maintained and operated varied greatly among facilities and facility types. Moreover, this variance would become crucial to estimating, guaranteeing and proving cost savings, or more specifically, 'avoided costs.' There are many buildings in differing industries in which maintenance procedures are clearly outlined and service is carefully documented. Whether a formal maintenance management program is utilized or not, the process is careful and consistent. It is more characteristic of some industries to simply respond to failures and operating

irregularities. As we might surmise, this makes it difficult to forecast accurate savings over an entire year.

In terms of achieving all of the *potential* savings from energy measures over the life of an energy project, the *value* of maintenance and operations to the overall economic success of a performance contracting project is often well over 50% of total cost reduction opportunities following implementation. As many of us learned during the course of longer-term agreements, these cost avoidance economics are far more substantial than one would suspect over the contract's entire term. Because of this, conflicts regarding how equipment had been maintained and operated arose when avoided cost results began falling short or deteriorating over time.

Let me take some simple examples. To save operating budget dollars, a large retail store elects to reduce the number of filter changes made to its large air-handling units from once every two months to once every four months. They also elect not to perform annual cleaning to the heating and cooling coils within the units. This simple deletion in maintenance adds additional resistance or 'pressure drop' to the overall system. The additional pressure drop causes the fans to supply less air to the spaces. Believe it or not, these systems will actually be *saving* energy! Of course, they are providing less heating and cooling to the space being served and, through the reduction in maintenance, store management has consciously sacrificed comfort and air quality to occupants. How do we account for the reduction in maintenance when developing energy measures in this case? Similarly, when other systems are under-maintained, energy use is often at reduced levels. A percentage of burned out light bulbs uses less energy, as do pumping systems with clogged strainers and filtration systems.

Additionally, it is critical to consider the non-economic value of operating a building with new technology, new systems and new practices, since this directly relates to the comfort and productivity of occupants.

While this is a fairly straightforward conceptually, a ten-year contractual commitment, such as featured by many performance-based projects, requires a 'big picture' analysis allowing such issues to be fully considered. This is best addressed by a system-wide building 'life-cycle' analysis.

A 'life-cycle' analysis is the best approach for assessing all costs and benefits associated with a group of measures. It entails modeling those

costs and benefits over the life of a performance-based contract and over the expected life of installed equipment and systems. Generally, most performance-based projects clearly define and include the estimated installation costs and construction period costs and savings, primarily for financing reasons. It is not always as common for a sound, life-cycle analysis to become part of a project's economic documentation. Just as an open-book pricing approach allows all parties to assess the costing and risk aspects of the project's *implementation*, the life-cycle analysis allows all parties to assess the long-term effects of the decisions which will be made in *defining* the project. This is even more important when you consider that those principally involved in initial project development and negotiations have often moved on to different roles well before these contracts expire.

When a life-cycle analysis is not performed, a project's economics are often falsely weighted toward first costs of installation measures, using simple payback criteria. Note: most ESCo's, *including those whose primary business has been related to product sales and customer service*, have proven traditionally to be weak in assessing long-term maintenance and operations needs. Further, they have proven weak in assessing the overall impact of maintenance and operations on the financial outcome of their performance-based projects. Less operationally sophisticated ESCo's are quick to look for opportunities to reduce the number of operator labor hours required by their proposed measures, and may reflect these "savings" in their economic analyses. More often than not these labor reduction assessments prove naïve.

"Win-Win"

Although the concept of 'win-win' has become a common cliché in recent years, the concept remains valuable for determining the viability and success of performance-based work. Long term projects, particularly performance-based projects, are most successful when those involved can point to some aspect of their project and see some direct benefit from their respective points of view. The goal of performance-based projects extends far beyond upgrading automation systems in buildings, creating positive cash flow, and reducing end-user energy bills to pay for capital upgrades over time. These projects are *successful* when all parties clearly sense that they *benefit* from the project's success. Some of the benefits are intangible, but over time they can become more important than avoided costs.

To understand the needs of all building “constituencies,” it is helpful when developing projects, to interview heads of departments to understand the occupancy patterns of groups that often work late hours, as well as boiler room engineers, custodians and cleaning contractors, mail room personnel, office managers and security people. Far too often, when some or all of these vital groups are omitted from the process of due diligence, the long-term effects are devastating to the project. For those who have been involved in shared savings projects, it is frustrating to recall situations in which an owner’s HVAC technician is reluctant to implement a cost-saving idea because he does not want the ‘ESCo to get credit’ for (all or a portion of) the savings resulting from his/her ‘ideas.’ Of course this seems naïve and petty, but it indicates that the building staff has not been included in developing the project in a ‘win-win’ scenario. Years after being confronted with this very issue, I sat in on a meeting involving an ESCo and the owner’s key operating staff. The ESCo announced that it would present a special ‘conservation partner’ award with a bonus for an idea brought to the attention of the project team resulting in a cost-savings opportunity for *their* company! Naturally, this project got off to a more favorable start.

To some performance contracting ESCo’s, ‘win-win’ means, “Give us the contract, and we’ll figure out how to keep the key people in your organization happy.” This really does not work over the long term. ‘Win-win’ means that all occupants, all departments and everyone involved receives some value from the project’s implementation over the duration of the contract term.

DEFINING ‘OPERATIONS AND MAINTENANCE’

It is important to define exactly what ‘Operations and Maintenance’ means, particularly as these terms apply to performance-based, energy services projects.

Operations

Operations is a term most frequently used to describe the process of how building systems and equipment are operated by staff to meet desired building conditions throughout the various occupancy and seasonal cycles. This includes when to start systems and equipment from both a time-of-day as well as seasonal standpoint. It also includes under-

standing how systems are controlled, sequentially operated and monitored. It also entails determining what combination of building systems should be made operable to meet varying, building load conditions.

Operations also includes practical planning for reliability, comfort, safety and efficiency as well as prioritizing systems and circumstances (various operational scenarios such as power failures, loss of cooling to a data center, etc.), which may require redundancy and contingency planning. How systems are operated varies by building type, use and system application. HVAC systems should be operated conservatively in, say, an art museum or a hospital operating room, and equipment redundancy is far more critical to these situations than it might be to a movie theater. Sound building operations practices are best characterized as reliable, comfortable, safe *and* efficient. Many times, buildings are operated by sacrificing efficiency for comfort and reliability, or by sacrificing comfort for efficiency as automated control sequences are overridden. Most often, this is quite unnecessary, and reflects a general lack of understanding of systems by building staff, more than it reflects a lack of planning, or lack of management's willingness to spend money.

Most non-equipment specific energy savings opportunities occur because building staff is operating major systems too conservatively. A building's use and occupancy may evolve over time, and sometimes, this requires making some adjustments. However, many of those responsible for building systems do not understand how efficiencies can be increased without sacrificing critical reliability. Frequently, long-time HVAC people balk at converting a constant-volume air system to variable air volume because they fear a loss of reliability and comfort. Quite to the contrary, a new, VAV system would result in a far more reliable and comfortable system, assuming it is designed properly and monitored well. The performance contracting business represents an opportunity in many parts of the country because building staff personnel capabilities are limited to observing problem symptoms, as compared with understanding design applications. An ESCo project allows for a system-wide approach toward re-establishing and achieving the comfort of all building occupants, but not without sound operating practices at the core.

Maintenance

Maintenance is a term that is, surprisingly, often misunderstood by building and facility staff. When inquiring about maintenance for new systems in a building, all members of the building staff do not intuitively

understand that equipment maintenance may be required as soon as equipment begins to operate. Unfortunately, this is a common and sometimes, fatal mistake. This would be like buying a new car with a one-year warranty and choosing to dispense with all of the manufacturer's recommended maintenance and service for your new vehicle throughout the warranty period, because you believed that any repairs would be at the manufacturer's risk and expense anyway! While you would probably be lucky during the warranty year (and save a couple of bucks in the process), the future for your vehicle in later months and years is likely to have been negatively impacted by this approach. Here is some news to managers of building maintenance staff: Your equipment's warranty period does not constitute a 'maintenance free' time period. While it is unusual, manufacturers may even deny warranty services if it is evident that required maintenance has not been performed, and it may be determined that a lack of maintenance is primarily responsible for an equipment failure. A name has even been given to this approach to or "type" of maintenance. It is called "breakdown maintenance." It is even appropriate at times relating to smaller, packaged equipment where there really isn't much to do until the machine fails, or the added value by regular attention is excessive relative to the small cost of the particular machine or system. Usually, though, in this author's opinion, it is done out of ignorance or stupidity—as will be discussed in the following.

It should be stated that good maintenance practices during warranty periods might often detect some of the more subtle warranty-related problems, which may have otherwise gone undetected until after the warranty period had expired. Why would anyone intentionally defer performing recommended service during warranty and take that chance?

In fact, it is very important to start servicing and maintaining equipment and systems per manufacturer's recommendations from the first day of equipment use. In critical system applications, it is often wise to use 'benchmarking' to assist with detecting problems at later times. An example would be a new reciprocating chiller installed to serve hospital operating rooms. Service providers might suggest that facility owners contract with a testing company for a system vibration test, sometimes called a *foot print*, and to be sure to schedule some early compressor oil testing, perhaps even as early as after 200 hours of operation. These activities may help to set the stage to detect any abnormalities, even minor cases, and to allow corrective measures to be considered well in advance of more pronounced symptoms of a problem.

Equipment and systems should be maintained based on the nature of their use, but also based on their frequency of use. Failures are less likely to occur in equipment which is operated continuously in a clean environment, and more likely to occur in equipment which has seen many 'starts' and 'stops' during its use, or operates in a less clean environment. Continuously operated systems should be scheduled to shut down for service at recommended intervals (usually based on hours of operation), and not only when 'convenient.' Equipment, especially of a critical nature, with many start/stop cycles should be inspected and tested more frequently, just as is the case with commercial airplanes for example. There was a case involving a small reciprocating chiller, which provided crucial cooling to a hospital recovery room. The supervisor had noted that the machine had started to make a shrill noise, and, over several months had become more noticeable. When asked why he did not schedule a shutdown, the explanation offered was that this system was 'too critical' and that it would have to continue to operate unless it failed, at which time a service call would be placed! It was obvious that this system was experiencing a bearing failure, and that the equipment was crucial to the organization's facility. But why would a responsible individual not address such a problem? It happens more often than we might imagine. To go back to an automobile example, would we be inclined to allow our spouses and children to continue to drive back and forth on busy highways, if our vehicle were experiencing the early stages of a wheel bearing failure? In these cases, failure is 100% *certain*, while the timing is 99.9% *uncertain*. Which brings me to a key point in discussing the design of a maintenance program for ESCo projects.

"Periodic," "preventive" or "predictive" maintenance is a *scheduled* activity. Repairs are *sometimes* scheduled, but are more often made, of course, in emergency situations. Most emergency repairs are avoidable and are the result of a failure to obtain or act upon some level of information, which may have given an indication as to the looming failure. When maintenance is deferred, operating information becomes unavailable. When information is not available, problems are more difficult to anticipate. Therefore, it becomes difficult to take action that might avert failure.

Incidentally, the cost of failure and emergency repairs is often several times the cost of performing regular maintenance; so cost minimization is rarely a viable rationale. Unfortunately, this is exactly how many facilities managers conduct their maintenance 'programs.' In a perfor-

mance-based contract, it is best to set the tone for scheduled maintenance and good documentation, early in the process. If the ESCo takes the lead with this activity as part of their contract, that is great. It indicates that they clearly understand the importance of developing a long-term plan for the project. But if they do not, building personnel should develop a more formal maintenance process prior to signing the contract. Systems cannot offer true, life cycle cost avoidance if they do not operate reliably.

Concerned about extra or hidden costs? In most ESCo projects, actual *maintenance* costs should stay about the same after project installation, if the number of system components remains constant, and the hours of operation stay fairly constant. However, the repair costs should be minimal for the duration of the contract period.

ORIGINAL DESIGN PERFORMANCE (ODP)

For every performance-based project, conservation measures will include some combination of new equipment, new controls, new operating conditions, fuel-switching, or technology advances. For each measure, there will be a new *design performance* specification, which will determine how this measure changes the original design. The interpretation of the each measure will constitute the contract's Original Design Performance condition, or ODP.

In order for each measure implemented to continue to deliver its contractual cost avoidance results, that is, its portion of the guaranteed savings, the measure must *maintain* its ODP throughout the life of the contract. Any factors, which reduce the measure's effectiveness, or alter its operating conditions or sequences, will have an impact on its results over the term of the contract.

It is, therefore, extremely important that a performance-based contract clearly spells out who is responsible to maintain each measure's ODP, and how this will be approached and documented. We are familiar with the concept of stipulated savings in a performance contract. For some measures, it is quite acceptable to 'declare' the savings of a measure beforehand, and allow this stipulation to carry throughout the term of the project. The classic example of this is replacing a T-12, fluorescent light bulb with a T-8 bulb. It is fair to state that each replacement bulb installed would represent a fixed cost avoidance, depending on bulb sizes and quantities. What remains dependent, are the hours of opera-

tion. For most measures, savings calculations may be more complex and involve interactivity of other measures. Because of this, many measures cannot stipulate savings while the performance of installed measures must be 'maintained' throughout the contract term. A manufacturer supplying new equipment can assist in developing benchmark ODP conditions, and then help to verify them when required. ODP becomes part of the contract's life-cycle expectations. It is not acceptable for the performance of installed measures to erode over the term for unknown reasons, but this happens far more often than we might anticipate. Once the erosion of performance has begun, it is very difficult to start over and re-establish the measure.

It follows that manufacturer's recommended maintenance and service procedures be designed to maintain the ODP of each piece of equipment it sells, indicated most often by its accompanying submittal information made available at the time of delivery. It also follows that for any service agreement to be effective, it should be less focused on generalized tasks and frequencies of maintenance tasks than on *manufacturer's recommended procedures* and the maintaining of the equipment's ODP. It is strongly suggested that, upon entering into a performance-based energy project, that all critical service agreements be re-written to reflect the responsibilities involved, and the circumstances under which changes to ODP conditions may be required. Using the manufacturer's factory service personnel to evaluate equipment on an annual basis would be an excellent inclusion to any long-term, performance-based contract.

IDENTIFYING CRITICAL OPERATING ISSUES

During the implementation of most energy projects there are operating issues, which should be identified as critical. These are not always straightforward. For example, there is a school, which was built in a high water table area and flood zone. The building's main switchgear was installed in the basement, and had been flooded several times. In developing this project, it seemed that this situation was not only potentially harmful to the success of the project, but very dangerous as well. The school district installed some standard, commercial sump pumps, the first of which was about a foot below the floor surface. The other was installed about 6 inches lower than the first, in a different sump. It was

decided that since potential flooding was so critical to the reliability of all building systems, our team would redesign the building EMS to monitor the sump pumps until arrangements could be made to elevate the switchgear out of harm's way.

Similarly, there are systems in all buildings, which are more critical to the nature of its operation than the majority of others. This being the case, it is prudent to pro-actively identify these systems and pieces of equipment *during the development phase* of a performance-contracting project. Special attention should be made to document the effects any program measures might have upon any of these critical systems. Of course, it is also worthwhile discussing how these situations may be enhanced through the performance contracting vehicle.

On a project involving a moderately critical chilled water application, it was known that rigging (moving) a back-up chiller into the building for redundancy purposes would be nearly impossible, and certainly, economically undesirable to the project. Because redundancy was so critical, plans were designed to run chilled water and condenser water lines, as well as a 460-volt circuit to the back of the building, where a staging area for an emergency chiller was set up outside the back wall. In this way, a commercially available rental chiller could be hooked up easily and be up and running in 24 hours in the event that the primary chiller became unavailable. It is this type of planning that should address every system and piece of equipment deemed critical to the building's operation.

Most often, the types of critical systems at a site are exactly what might be expected: life safety, security, process applications, low-temperature applications, building power systems, gas-fired equipment, data center equipment, handling of hazardous wastes and critical pumps or fans. Often there are code compliance issues, indoor air quality impacts or other sensitive environmental issues. For each critical system identified in the performance contracting project development process, there should be an operating and contingency plan.

The Value of Diagnostics

The subject of diagnostic services (i.e., "predictive" maintenance) can fuel a heated debate among test engineers, facilities people, equipment operators, service companies and equipment manufacturers. It would be safe to say that any information which could be easily obtained and be instrumental in preventing emergency repairs, extra repair costs,

inconveniences and other problems, should be worthy of consideration.

But just how valuable are some of these diagnostic procedures and which ones are the most critical?

There are several methods of common diagnostic testing, which are routinely performed. The following is a brief, layman's discussion on the merits of each.

Oil Testing

Taking an oil sample from a compressor is the equivalent of taking a blood sample in medicine. Oil that has been lubricating equipment over some period of time can reveal a number of operating subtleties to the trained observer. Keeping things simple, when an oil sample is analyzed it will reveal traces of various metals and elements absorbed from natural wear of the machinery it lubricates. When oil becomes 'dirty' the concentration of these substances can reveal whether or not equipment has been operating normally, or shows signs of abnormal wear and tear. This allows technicians to investigate situations which may require some attention in the coming months, often assessing whether repairs can be deferred and scheduled during off-seasons, or whether failure may be right around the corner.

The oil analysis can also tell us about equipment efficiency and conditions in other parts of the system. Simply changing oil annually cannot tell us anything about equipment, and although it is common, should not, in itself, become standard procedure when maintaining building equipment. An oil sample analysis costs about \$50.00—certainly a worthwhile investment when considering the cost of emergency repairs vs. corrective action.

Tube Testing

Testing tubes for wear can tell us about the integrity of the vessels (chillers, boilers, heat exchangers). Tubes are engineered for heat transfer in these vessels and efficiency is optimal when all tubes are intact and clean. After many hours of use, tubes may wear at certain points depending upon the construction of the vessel and the material used in manufacturing the tubes. A rupture in a tube wall creates a failure requiring timely repair.

Testing chiller tubes during convenient times, such as while winter maintenance is being performed, can be very cost effective considering the alternative of a tube failure. This requires that the machine is taken

off line, and torn down for repairs. The reason tube diagnosis is cost-effective, is that chillers are designed to operate with a certain number of tubes. The most important thing to consider is the integrity of the equipment and the condition of the tubes on which it depends so heavily. If we test tubes every 3-5 years of vessel operation (depending upon the hours of operation), we can anticipate when it may become time to re-tube a vessel bundle to keep our equipment at operating at 'ODP.' While the wearing of a tube may not be able to help us diagnose a system to the extent that an oil analysis can, at about \$1.50/tube, tube testing can save a lot of additional costs and inconvenience over the life of a chiller.

Electrical Testing

If oil can be loosely compared to 'blood' then a building's power is like its 'nervous system.' When a building's power is down, it becomes paralyzed. Performing basic power diagnostics such as circuit studies and thermography can help detect problems and code issues, which can affect life safety as well as efficiency and comfort. An electrical testing program may involve lockout-tagout studies, code compliance assessment, overload testing, load studies, and circuitry evaluations. Thermography looks for 'hot spots' in switchgear and motor control centers. Every year, we read about companies, which are fined by OSHA for electrical code violations. Worse, every year we become aware of some industrial disaster emanating from a building's electrical system. Since the safety issue implications are so high and the efficiency improvement opportunities are vague, it might be advisable for every building's management team to undertake a diagnostic electrical testing process at least one time, and, depending upon the frequency of changes being made to the system, addressed periodically. Why not look at these systems before implementing a performance-based project? Depending upon the size and nature of equipment, the testing costs 10-20 cents/square-foot, and can be quite revealing.

Vibration Testing

This subject is a little more controversial. Vibration testing involves a series of impulses, which, when taken at various levels of operational output, provide an *acoustic footprint* profile for a piece of equipment. A similar footprint taken at a later date, under exactly the same operating conditions, readings may reveal a slight 'change' involving a component, such as a high-speed shaft, and thus alert maintenance personnel to an

imminent failure that can be averted.

Pervading thinking says that for critical, high speed equipment that operates at *exactly the same* output all of the time, there may be benefits to comparing vibration tests to detect pending failures. When some equipment, such as chillers, operate at varying outputs at all times, a vibration test may be a moving target, and would be of little use. It would be prudent to contact a qualified and recommended vibration testing company to determine the value of testing any high-speed, critical equipment under consideration. The dynamic vibration testing process that can determine whether or not a piece of equipment may have been installed 'out of level' since a piece of equipment's position may slightly change during operation, and it may be difficult to detect without some level of dynamic testing.

Manufacturer's Performance Tests

Manufacturer's performance tests are those (almost always) performed at a manufacturer's factory to ensure that equipment performance is 'as advertised' or as reported in submittal data at the time of equipment sale. It is important to note that no two pieces of manufactured equipment will operate exactly alike, either during testing or in application. That said, every major manufacturer fully guarantees the performance of the equipment they sell. It is likely that trying to conduct any on-site performance testing would be costly and unnecessary. In conducting field performance tests, there is no evidence that supports whether these tests confirm or verify anything of reliable substance. Instead, it may be prudent to spend the time and money testing the distribution systems, which will be critical to serving replacement equipment and the operation of installed conservation measures.

Other Tests

There are a variety of other diagnostic tests, which involve primary equipment and distribution systems. Testing steam traps is an example. It is worthwhile contacting manufacturers of existing building systems to see what testing is recommended, and at what intervals.

EXTENDED WARRANTIES

Extended warranties offer some interesting options in efforts to mitigate performance contracting risk. Most manufacturers of major

building equipment offer extended service programs with the purchase of new equipment. The most commonly known extended warranty is the optional five-year warranty for rebuilt replacement compressors. Particularly attractive for multiyear situations, the extended service agreement, or extended warranty, allows the ESCo project developer to hedge risk in later years and more accurately assess annual project cash flows.

In essence, the risk of catastrophic failure is hedged over the term of the agreement, as well as its being hedged statistically over the manufacturer's portfolio of new chillers covered under their extended warranty program. Here are the advantages:

- The cost of the extended warranty or service agreement is pre-determined and paid in advance, thereby becoming a known project cost.
- Annual cash flow guarantees or cost avoidance can be offered with far less risk, particularly later in the contract term. Risk of catastrophic failure can jeopardize the project's financial returns. These agreements ordinarily 'pay for themselves' if one claim is involved over the term.
- The rewards for good documentation and service are enhanced by the terms of extended manufacturer coverage. Since documentation is critical to filing a claim, service records will likely be better managed over the term of the ESCo agreement.
- The cost advantages of extended coverage on new equipment are very favorable. The overall, ten-year cost of extended coverage vs. a series of annual, total maintenance contract with equipment manufacturer may be as low as two-thirds of the total amount spread over the term! Most service organizations will attest to these numbers. When you think about it, the numbers make sense. In an annual service agreement, the 'risk' of failure must be carried as a cost annually, and cannot be hedged against other years and other contracts in the portfolio easily. The fact that a major failure may not have occurred in a previous year is irrelevant to current year's pricing. As a result, annual total maintenance agreements are cost estimated very conservatively, meaning the pricing will be high, especially as equipment ages and statistical probability for certain failures increase.

- If the service agreement is limited, that is, it does not provide for coverage of catastrophic failures, then the facility must bear the financial risks. This might be like living without auto insurance. This would be advisable only if the contracting organization can afford the financial risk of a major accident! Since most performance-based contracts are multi-year, it is most prudent to make decisions based on the overall contract term.

Are there downsides to extended warranties? The answer relates directly to situational risk tolerance. If an organization could not afford hefty repair costs associated with a catastrophic failure during the ESCo contract term (and lost cost savings may be incentive enough in a performance contracting project) then it would be advisable to consider the most cost-effective extension of warranty available.

The extended warranty should be purchased directly through the manufacturer. The value of third-party warranties cannot be assessed easily.

APPROACH TO SERVICE CONTRACTING AND ON-SITE MAINTENANCE FIRMS

This is a very timely topic. If you are reading this book, you have a general understanding of the maintenance contracting business. Let's dig a little deeper to consider how the service industry works. Signing a performance contracting agreement may signal a good time to reassess how the contracting organization handles its maintenance services.

We have discussed the concepts of maintenance, operations and 'Original Design Performance.' Now we assess the needs of the end users as well as the motivations driving subcontractors. Intuitively, we understand the need for taking proper care of equipment on which our buildings depend for comfort and safety. In actuality, we would hope to experience:

- Long equipment life,
- Sustained efficiency,
- Reliable and safe operation,
- Minimal disruption to facility occupants

In addition, we would like to associate as little expense with these objectives as possible over the long haul. There are several approaches to achieving the goal. Among the most common:

- Hiring on-site technician(s),
- Subcontracting equipment maintenance and repair with manufacturer's service organization,
- Subcontracting larger HVAC equipment with an independent mechanical service contractor,
- Subcontracting with an on-site maintenance firm,

We will briefly examine these within the context of our stated needs, and demonstrate a logical way of determining the best approach.

Hiring the On-Site Employee

If we were to hire an on-site technician to maintain, repair and operate equipment, there are several factors, which come into play immediately.

First, we must commit to adding personnel to our staff who, by the nature of the maintenance function, cannot contribute to the profitability of our organization's goals or business, and who are not engaged in the core activities of our organization (unless we are in the maintenance services business to begin with...). This means we are unable to provide internal training, and must hire into the staff, someone who is already qualified to perform the recommended scope of services required. In addition, we must be prepared to provide regular, outside training, and must determine how best to keep the employee(s) abreast of safety and environmental issues impacting the facility. Depending upon the individual(s) brought on board, the prime motivation of an employee filling such a role is likely to remain gainfully employed (i.e. 'keep a lid on things,' and 'not rock the boat'). Realistically, the employee knows his/her career options are limited within the organization.

If we are lucky and can acquire a motivated, ambitious employee, or maybe a 'genius' (see 'Good Will Hunting'...) we may be able to achieve many of our goals. There have been exceptional site employees, ranging from accomplished auto mechanics to self-taught computer ex-

perts. These folks are exceptions to the norm. Even if an organization is lucky, however, it is still assuming responsibilities for benefits, covering vacations, frequent turnover, training and other risks. There are also costs associated with expensive tools and equipment, even if only occasionally used by site staff.

It is easy to see where I am going with this argument. Experience has pointed toward hiring a good site person to work within the organization's interests up to a certain level of expectations. But it has not been proven cost-effective for an organization should try to assume the responsibility of maintaining critical 'ODP' for more complex systems and equipment with in-house employees. Performance contractor's who offer to 'pay' site employees to handle any of the complex tasks associated with new equipment and measures are generally unsophisticated when it comes to operations and maintenance.

Experience tells us that when we hear a Facility Manager mention that he utilizes in-house chiller technician(s), it conjures an image of a classic situation. It is almost certain that maintenance is not being done per manufacturer's recommendations, that the technician is likely 'underqualified' as well as inadequately equipped, and that the organization is receiving minimal benefit and shortened useful life from the equipment. Efficiency is almost never being monitored. Diagnostics are virtually never part of the program.

This is a shortsighted, yet common approach, and, most important, is not compatible with the *long-term objectives* of the performance-based contract.

Hiring a Manufacturer's Local Service Organization

Hiring a manufacturer's local service organization is another approach. The manufacturer's service team is, by definition, *factory-certified* to perform all levels of service associated with maintaining and operating factory equipment. This means he/she has attended classes, studied the manuals with regard to procedures, practices and troubleshooting, and is likely to have had recent experience in starting equipment upon installation.

The risk of poor workmanship or ignorance in servicing equipment is very low. As an example, it is a virtual certainty that a factory certified technician would 'jumper-out' a safety to keep equipment running and then leave the site, because he/she would clearly understand the risks involved. When this does happen, it is most likely the work of on-site

personnel or an under-qualified, independent service company.

Using the manufacturer's service team can be expensive, but if a contract is structured properly, it should be a cost-effective approach. For example, we might not necessarily include tasks in a service scope that do not require the skills of a factory-certified technician, such as replacing air filters or removing vessel heads for inspection, or spray-washing air-handling unit coils. If a service contract is structured well, the cost of using factory-trained service personnel should be reasonable, and involvement by a trained professional should be able to avert problems not easily detected by others. This can be crucial to cost savings guarantees.

The motivation of the factory service team is to entice building people to continue to buy their equipment and parts, and to offer favorable references to those considering a purchase of similar equipment. A manufacturer wants to maintain and grow its equipment and service market share, and ordinarily does that by seeking to improve its reputation. Most often, problems with a manufacturer's service organization are those resulting from carelessness or competency issues within local offices, and are most often related to follow-up or scheduling.

Hiring a Local Independent Service Contractor

Contracting with an independent mechanical service contractor is a little riskier. There are no assurances that technicians, particularly across the board within any independent organization, are of the same caliber as the factory-certified technician, nor can an organization be assured that a technician has had adequate and up-to-date training to properly provide services. Factory certification is not a 'life-long' designation. If a solid technician left a major manufacturer ten years ago to join an independent firm, there is little assurance that the technician's education has kept up with current technology. While this was seldom a problem in past years, advances in technology and system automation throughout the 1990s have changed the landscape of the service business. Increasingly, the work of service and repair technicians is tied to rapidly evolving microprocessor-based controls and diagnostic systems. It is very difficult for independent service companies to remain current in their field organizational capabilities in servicing the many versions utilized by the different manufacturers. In the automobile industry, technicians are required to become certified to service new vehicle models and to update their certifications when required. This means they spend a number of hours at a company training facility and become familiar with the

latest electronics, maintenance and troubleshooting procedures. Although independent contractors will not readily admit it, the same principles apply to servicing building equipment.

It can be often said that an independent service company may be more responsive, feature reduced labor rates, and offer high caliber technicians. That aside, it would be wise to secure references, technician training certificates, and bonding and insurance information to reassure ourselves that the independent contractor may be the right fit to handle the servicing components of the performance contract.

Unlike the manufacturer's service organization, the independent is usually not 'loyal' to one manufacturer's products and systems. However, this also means that its service staff must achieve an adequate level of proficiency with equipment manufactured by *several companies* a more difficult training goal. The motivation of the independent service company is to build and maintain extreme loyalty between itself and its service clients. It should be easier to reach price concessions with independent contractors, and this may be a better approach to handling the less-skilled tasks, such as servicing air-handlers, cooling towers and pumps. There is no reason that an ESCo contract need only secure one equipment service vendor for most conventional projects.

Hiring an On-Site Maintenance Staffing Organization

Finally, the on-site maintenance staffing option is very similar to hiring an organization's own on-site employee, but does not entail the obligations associated with employment and benefits. It also allows for risk assignment in many cases, and includes 'built-in' vacation and sick-day coverage. This is a very good alternative for conventional maintenance staffs and usually involves semi-skilled labor, whose own organizations can be of great assistance in dealing with more complex problems and circumstances as they arise. Some of the better companies will allow for a pre-screening of staffers designated for these assignments.

In conclusion, experience has shown that it is best to make an honest assessment of how equipment and system maintenance needs should be addressed for a given situation, and to be sure that the skill levels and overall competence of those assigned these tasks match with the service levels required. Once a performance contract is under consideration, maintenance should no longer be 'business as usual.'

THE IMPORTANCE OF INFORMATION TECHNOLOGY

One of the emerging issues which inherently link O&M management to the success of the performance contract is the development, implementation and utilization of information systems to manage a performance contracting project.

More than ever, opportunities are available for project personnel to gain immediate access to a wide range of project data and information. With these opportunities available, and others emerging regularly, everyone involved in a project should have regular access to information deemed crucial to that project's success.

It is now possible through low-cost automation to provide data points, which can compare current operating conditions to benchmark conditions, even on an hourly basis. It is easier than ever to determine even minor irregularities in operating conditions, and for all project members, meaning those from the contracting organization, ESCo project members, service vendors, and others, to jointly address unusual operating conditions. This is a great weapon, and can strengthen the 'win-win' premise upon which the performance contract is built.

With advances in technology, reduced costs to automate, and the opportunities provided by the Internet, we now have the ability to capture more information, create additional tabulations and calculations, and distribute data quickly and efficiently. One of the limiting factors of the performance contract of the earlier ESCo days was the 'time lag' in obtaining meaningful information in a timely manner, and being able to manage the M&V (Monitoring & Verification) process to assure optimal operating cost avoidance.

The best starting point in developing an information strategy for a performance contracting project is to assess current building automation systems (BAS), or, also formerly known as 'energy management systems'—EMS). Questions we could ask are:

- Does the current point listing make sense within the context of the performance contract?
- What are the most critical 'O&M' elements of information needed for efficient operation?
- Who needs this information immediately?

- How can we use the BAS to assist us with optimizing energy use from an operational perspective?

In the new millennium, it makes sense to consider Internet based options with graphical user interface as a means of distributing information and providing more immediate feedback. The initial investment costs are likely to prove justifiable considering the duration of the performance contract term.

It would be prudent to speak with a number of qualified BAS vendors, Internet developers and building operations people, including those promoting independent systems, to get some ideas for creative communications solutions.

Designing the Proper O&M Program

Automated Maintenance Management programs are fairly sophisticated as we write this chapter. A key consideration to selecting and designing a Maintenance Management program is identifying operational priorities within the facility. Maintenance Management is no longer simply about changing filters every three months, but is more focused on ensuring the reliability and efficiency of all systems based on their operational profiles. The latest generation of maintenance management programs can identify chronic problem areas that require immediate action, to inventory critical parts, and to develop redundancy plans.

The goal for the Maintenance Management program should be consistent with the performance contract goal of maintaining 'ODP' for all measures, in part by minimizing equipment down time throughout the contract term.

The conventional premise for building automation is to set operating parameters for a building's systems, and use the BAS to maintain those conditions and 'report' abnormal conditions. In the early days of BAS software development, the result was a never-ending stream of 'alarms' that required a dedicated system operator to 'acknowledge' as conditions were 'reported.' Often, these were simply temperature variances. Ultimately, the systems operator would simply tap the 'ACK' button a dozen times every half-hour without looking at the actual reported conditions.

Our approach to automation is far more sophisticated these days. In fact, technology allows for more meaningful operation with BAS assistance, as today's systems can now 'learn' about the operating condi-

tions of systems. Those who began their careers in the buildings controls industry can attest to the fact that early BAS systems were overly complicated, cumbersome and costly. While there is a tendency to believe this was intentional, and perhaps, a 'conspiracy,' this was probably not the case.

Consider instead that controls companies had been primarily manufacturers of technical devices and systems. The understanding level of *actual building systems operations* by these folks was minimal. Therefore, the majority of systems and operating software were developed without a solid understanding of the very systems being controlled. In addition, because controls engineers themselves found the systems to be relatively simple, they often created what proved to be overly complex and large systems in terms of their manageability by building staffs. Think about this—if we were to design a BAS for a large, commercial property today, would we really require upwards of 2,000 controls points?

This period really represented a learning curve in BAS use, just as the programming of early PCs during the same period was a learning curve for that industry. However, if buildings are still using 1980s vintage BAS today, it would be the equivalent of having our current PCs being capable of only playing 'Pong' on our video games!

For an ESCo project, BAS should be used to measure and monitor the use of water, gas, power, steam and fuels. It makes sense to consider sub-metering of systems for better project management. Reduced costs for data points make this more practical than ever. In addition, metering technology has advanced substantially, giving a far more accurate representation of how and when utilities are used. It makes little sense to spend dollars in efforts to provide complete space temperature sensing. Each individual occupying a space varies on his or her definition of comfort. Our job in developing the best BAS is to provide the most cost-effective means to producing the broad range of conditions required within the facility, and to be certain that we can have access to immediate feedback on operating conditions.

The most recent versions of popular automated CAD programs allow the graphical interface to link pictures and other data to standard CAD drawings. For example, we can now set up a standard CAD drawing, and with a click of the mouse, see a drawing focused on the electrical distribution system. With another click, we can look at a single circuit. We can click the motor control center and see a picture of it, or we can toggle through information such as manufacturer, make, model, break-

ers, etc. We can click the HVAC system and get a listing of all equipment, as well as recent maintenance or parts used on a specific heat pump or chiller, including as much specific information about components as we care to load into the file.

Should a remote retail space in upstate New York experience trouble over a weekend, it is now possible for a Project Manager in Chicago to access a file over the Internet, check the systems in a building, research critical component information and take action to correct the problem. The opportunities are boundless. For those who have read Bill Gates' "The Road Ahead" there are plenty of parallels that we can draw from his examples of how the information superhighway may serve an ESCo project. The future is here, and access to information presents the next logical step in available building operations technology

The 'Virtual Project Team'

One of the greatest benefits of BAS technology and a more thoughtful approach to using BAS and the Internet in an ESCo project, is the opportunity to assemble a 'virtual project team.' The more information available to members of the ESCo team, the more likely a member of that team can contribute positively to the outcome of the project. It would be prudent to review the automation plans with communications engineers from one of many emerging suppliers. The ability of ESCo project developers to create a situation that allows several key team members to easily access project information and provide input may determine success in future performance-based contracts. The project information relates to operations, service, emergency response and maintenance.

The real advancement in managing the ESCo project for the new millennium is the leveraging of such technology. Once, a Project Manager for a performance contracting team would work endlessly to gather and compile data, to compare normalized results and create reports. Now information and results are immediately available, and available to everyone interested in the outcome of the project. This means that the ESCo's Project Manager can view results at 7:00 AM and immediately have a discussion with building operators who are looking at the same information. Through the use of technology in building operations, the number of contributing members to the project's success is limitless. The critical link between the ESCo's in-house team and the client's site staff is operations.

ESCo CONTRACTING CONSIDERATIONS

From a building operations and maintenance perspective, there are several key considerations in selecting a performance contracting company or ESCo. Not all ESCo's work the same way or function within the same context.

With the emergence of new 'market drivers' representing the new breed of ESCo's, it is important to consider both the origins and motivations of the players who now comprise the industry. We will address the subject of risks later in this section.

The industry has several long-standing ESCo's whose track records extend for over ten years. In just about every case, the origin of each company indicates that organization's strengths, and often its motivations.

Major controls companies, who entered the business circa 1984, did so to capitalize on their relative strengths working in the public sector, particularly public schools, whose primary hurdle was appropriating the capital required to make necessary upgrades to electronic controls systems. These systems were technologically advancing rapidly and unlike their predecessors, pneumatic controls, required software and hardware upgrades as well as operating support. While the controls companies were excellent at their core business, they would find they were not as well versed in the operations of commercial and institutional buildings as their performance-based businesses expanded into these markets. Project success and levels of client satisfaction were certainly less than 100%. This caused the 'Energy Services' business to suffer from a mediocre reputation. Those clients who had the foresight to bring in a qualified third party engineer or consultant to monitor and verify results and coordinate with the ESCo often had better results.

By the early 1990s the controls companies' ESCo's became well established and more capable of understanding the operational issues. They have documented success and learned to understand their failures. In many projects it has been realized that operational communications have prevented a higher level of success. While it has often been stated to the contrary, it is not unreasonable to speculate that the prime motivation behind controls companies entering the ESCo business was to increase market share of automated controls systems. Today these companies struggle to develop strategies to compete with the utility companies who are creating their own demand side ESCo's (sometimes referred

to as 'Retailco's') to enter these markets. From an operational perspective, the control company ESCo's have a "learning curve" lead in understanding the impact of maintenance and operations on performance contracting project success.

During the 1980s, regulated utilities created some the first ESCo's in the country. A few years later, most of these companies were sold off to other interests. Then in the face of deregulation, the utilities created new, unregulated retail companies to enter the ESCo markets once again. Many of these companies have recently become the featured market drivers in many areas. They are focused on developing heating, cooling and electricity plants and managing them for major national companies and industrial complexes. This, of course, stems from their strength in operating power plants for their own, regulated companies. Many are also looking at performance-based, build-own-operate deals as well. While these companies have a lot of dollars behind them as they start down this road, they are weak with respect to the competencies required to maintain and operate commercial and institutional facilities. Essentially, these are 'start-up' ventures that trail established companies in their knowledge of building systems and in having infrastructures in place. Given the origins of these companies, their objectives may be linked to future sales of long-term retail supply side contracts for power and gas.

Other players in the market are financially based. Their real expertise is their ability to secure attractive financing. Some of these firms are very successful, but they are usually limited in many of the required for performance contracting. Most likely these companies will rely on a third party to develop and manage the operational side of their projects. These companies may charge a fee for financing, while other companies may pass through financing without fees.

It is most prudent for a prospective client to first determine the nature of reasons for considering an ESCo project. Then, depending upon the need and resources available, the organization can create a profile for the type of ESCo it seeks. I am not sold on the use of 'Requests for Information' (RFI) or 'Requests for Qualifications' (RFQ) unless these are specifically tailored to the intended need and include an interview process to determine relative areas of expertise of the respondents. The selection should then be made based on that expertise. Otherwise, these processes can become a high-cost writing exercise for vendors. Such costs must ultimately be recovered from customers in some manner. The result

will be that the more 'in-demand' ESCo's will be those who do not choose to participate in these exercises, pointing to the slim margins available in retail gas and power sales.

Assessing all of the Operating Risks

Operating risks associated with performance-based projects are not unlike the operational risks encountered by facilities groups in everyday situations. The only complication is that there are other parties (namely the ESCo) with a significant stake in the process. While this chapter touched on these issues earlier, the importance of identifying risks bears reinforcement.

The first and most important step in an operational risk management program is to catalogue all systems and to identify the relative operating risks associated with these systems by establishing a listing of risk-sensitive systems and equipment. Some of the questions we might ask in order to assess the level of these risks, include:

- What happens when this system fails?
- How quickly is a response to any operational abnormality required?
- Who, within the organization, needs to be appraised of issues related to this system?
- Does this system require redundancy? Does this system currently have available redundancy? Is redundancy feasible?
- What are the costs associated with the operation of this system?
- What are the costs associated with *failure* of this system?
- What are the occupant and environmental safety implications related to the operation of this system? (NOTE: Should this system receive attention in the organization's 'Hazard Communications Plan' or other critical documentation? This may involve, for example, handling of CFCs, lubricants or solvents.)
- Are there clear and readily accessible procedures in place to manage operation of this system?

- Are the risks associated with the operation of the system clear to all members of the staff?
- Who is primarily responsible for the safe, reliable operation of the system?
- (Specific to a performance contracting agreement) What are the performance contracting implications associated with the operation or failure of this system?

There are probably several more critical questions we might ask in specific instances. Intuitively, there are likely to be several systems and system components that fall into a category of moderate to high risk. Once the questions have been developed and answered, the second step involves prioritizing the operational risks and developing contingency plans.

Without an energy services agreement in place, the above responsibilities belong to the facilities staff and organization occupying building space. The introduction of the energy services party requires that an additional step be added to the risk management process.

The ESCo and facility people should meet early in the energy project development process to identify how the operational risks will affect both organizations. Each organization has a substantial stake in the management of operational risks, and each must be willing to participate in the risk management process.

To the owner's staff: Your organization's signing of an energy services agreement does not alleviate the facilities staff of all risk-related responsibilities for the operation of systems, whether they remain as originally designed, or have been modified or upgraded for cost avoidance!

To the ESCo: Experience has shown that it is incumbent upon the ESCo's staff to articulate and reinforce operational issues to owner's staff. This may have a direct impact on your profitability! The owner's staff must be part of the planning process and part of the ESCo team to ensure operational success of installed measures. It should not be assumed that the building staff understands the impact each system or sequence of operation may have on cost avoidance.

Once each party realizes the dependency they likely have on one another, the ESCo 'team' may plan for operational success. At this point,

responsibilities of each party should be clearly outlined, and this process should include response time, notifications, communications, documentation, responsibility for costs, and all other issues addressed in the risk assessment. In this manner, conflicts during times of crisis should be minimal, and all parties on the ESCo 'team' will be working on the same page.

One final thought: The documentation involved in the operational risk management process is critical to the long-term success of the ESCo agreement. This is particularly true, since many (if not all) team members may change during the term of the contract. It is unusual that more than one or two people remain in place during the entire term of a 10-year shared-savings project. Imagine the wasted time and dollars if new members of the team are forced to revisit risk management issues 4-5 years into the contract term.

TEN STEP PROCESS TO SUCCESSFUL O&M PLANNING FOR ESCO PROJECTS

We conclude this chapter with a review of the steps which can help an ESCo project be as successful as possible from an Operations & Maintenance standpoint. The perspective is from a client organization's point of view.

1. Become involved early in the ESCo project development process, stay involved, and make certain you understand everything that is happening within the context of the ESCo agreement. Plan for a life-cycle, and plan to contribute to exceeding expectations for results!
2. Accurately assess the current quality of maintenance within the facility being considered for an ESCo agreement. Determine whether past and current maintenance practices are adequate and serve the purpose of maintaining reliable, efficient system operations. Attempt to assess the 'value' of the maintenance at this facility to the organization. Do not allow the introduction of an ESCo agreement to shortchange future O&M efforts by diverting attention from O&M.

3. Assess the 'Life-Cycle' costs and benefits associated with new equipment and systems being proposed by an ESCo. Try to avoid the trap of low first cost measures, which may offer better short-term economics, but may become an operation burden, or be less economically attractive over the longer term.
4. Determine the O&M benefits that would define a 'win-win' ESCo project for the long-term. Make sure that these benefits are addressed during the planning stages. Become a 'partner' to the ESCo and become part of the ESCo 'team.' The ESCo agreement is a contract which is most like a marriage—*It is critical to select an ESCo partner that is right for your specific organization.*
5. Request that the ESCo's references be interviewed from an O&M perspective. References that only verify energy savings achieved will not provide an indication of the ESCo's demonstrated ability to work within the context of the facility's day-to-day needs.
6. Understand that maintenance is a required and scheduled process. Do not assume that the ESCo will accept responsibility for all warranty and early maintenance tasks per manufacturer's recommendations. Your organization's goal is to maintain 'ODP' for the life of the installed systems and equipment, long after the contract has expired.
7. Require good documentation. Require investigation into the use of diagnostics to avert problems, validate performance, and to confirm reliability. Request information on extended warranties. Be certain that when the contract term expires, the equipment and systems have been turned over with minimal risk.
8. Determine the best approach to staffing and carefully review service contracts to be certain that the bases are covered and that unnecessary expense is avoided. Have a qualified third party review the service scope and suggest changes. Consider involving the manufacturer of critical or costly equipment early to ensure a good start to the system's life. Consider multiple vendor agreements for tasks requiring differing skill levels required. Focus on documentation and identify recurring repair expenses.

9. Use current information technology to compile accurate and timely data. Consider graphics-based enhancements to allow multiple members of the 'team' to have visual access to current conditions and avoid manual data compilation. Utilize the 'Virtual Project Team' within your organization, even if it means spending money to supplement the ESCo's automation system budgets.
10. Assess, evaluate and manage operational risks for the long term. Develop the plan, assign responsibilities for the risks and create a process that can be managed throughout the life of the contract term and beyond.

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Chapter 16

Minimizing Risk in Energy Performance Contracts

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INTRODUCTION

There have been many books written and papers presented regarding risks in performance contracts, especially for Energy Performance Contracts. This chapter will present some of the experiences and thoughts that this author has had in minimizing risks in Energy Performance Contracts. The slant of the chapter will be on how the End User can minimize his risks, and will be presented from experiences as an End User and as an ESCO. Risks discussed fall into the following categories:

- (1) Engineering risks
- (2) Implementation risks
- (3) Financial risks
- (4) Verification risks
- (5) The risks involved in selecting an ESCO.

The issues and points discussed here are the result of several years experience of the author in this field as an end user, an ESCo employee, and an independent energy consultant.

RISKS IN PERFORMANCE CONTRACTING

This chapter will restrict itself to some risks which impact the end user. It will provide a framework which the end user can use in negoti-

ating his contract for such projects.

First and foremost in negotiating the contract, the end user should recognize that he is an equal partner in the contract and he should use this opportunity to minimize his risks. Too often, the end user does not fully recognize all of the issues involved in the project, and when he finally learns them, it is too late. The end user should use this opportunity to develop a true partnership. Failure to do so will result in conflict and possible project failure.

Second, all parties in the contract negotiation stage will be attempting to reduce their risks to zero. While there is nothing wrong with this position, especially if you are the one to negotiate a zero risk contract, its practicality is somewhat questionable. In the true partnership, all parties to the contract share equally the risks involved in a project. In this manner, the "true partnership" will be enhanced. Additionally, it has been my experience that if an end user demands and gets a zero risk (to him) contract, he will have left a lot of rewards on the table, and he is not truly representing his company.

The risks discussed here are:

- (1) Engineering
- (2) Implementation
- (3) Financial
- (4) Verification
- (5) ESCo selection.

This is certainly not meant to be an all-inclusive list of risks, but rather, a few of the more important ones. The end user is cautioned to thoroughly evaluate the Performance Contract and project associated with it to insure that he has taken into account all of the contingencies which he believes are important and which will minimize the risks involved through a partner-sharing relationship.

ENGINEERING RISKS

The first step in entering into an energy performance contract is to perform an engineering or technical review of the project. The party making the proposal to the end user, identified in this chapter

as the ESCo, should have performed an energy audit, or site review, to identify potential Energy Conservation Measures (ECMs). Before any contract is reviewed or signed, this audit should be thoroughly reviewed by the end user. The end user should have his own knowledgeable and unbiased team of experts analyze the audit, the ECMs involved, and the costs and savings to implement the ECMs.

The audit should be reviewed for its thoroughness. Is it an Investment Grade Audit (IGA) or one of a lesser quality? Usually the ESCo will not perform an IGA unless financial commitment has been made. The end user might want to consider committing a limited amount of funding in order to get an IGA performed. The more thorough the audit that is performed, the less risk to all parties involved. Expenditure of money to perform an Investment Grade Audit may be money well spent in reducing his risks and conflicts at later stages in the project.

The end user should evaluate the proposed list of ECMs. Do they make sense? For example, a lighting ECM might be proposed which requires the conversion of lighting source to be changed to one which has poor color-rendering characteristics. This however, may not be acceptable to the operational or production staff. Another ECM may be Variable Frequency Drives (VFDs) on an HVAC system which is not suitable to such an application, such as a dual deck system.

The end user should also recognize that the ECMs will likely have an interactive component. It is important that he recognizes this and insures that any interaction is considered and accounted. Insure that savings are not double counted or that implementation of one ECM precludes the implementation of other ECMs.

The end user evaluation should also include a review of the materials to be used in the project. Reliability of the equipment to be installed is very important to the project, especially if savings are required to finance the project. Allowing the ESCo to have sole authority to choose equipment suppliers should not be acceptable. The end user should insure that he has the final, reasonable authority on this subject.

The end user should also be knowledgeable of other operational issues that are required by the implementation of the proposed ECMs. Such issues could encompass hours of operation required or the mode of operation necessary to meet the energy savings. For example, if the ECM is a lighting retrofit in a university or school setting, assuming

4,000 hours of operation per year is unrealistic; that works out to almost 12 hours/day 7 days/week. Additionally, changes in modes of operation may not make sense as well.

As previously pointed out, the end user should have his own team of technical experts to evaluate the ECMs. This team of experts can be composed of internal personnel, consultants, or a combination. The important thing to consider here is that the team is unbiased in their thinking. The end user's team, however, should be prepared to work cooperatively with the other partners in the project.

IMPLEMENTATION RISKS

As part of the contract negotiations, the end user should also be aware that there will be certain risks during project implementation. Probably first and foremost, is the timing of the project to be installed. Typically, all contractors like to work during the day, Monday through Friday. There is nothing wrong with this; in fact, there are usually a lot of good reasons to do so. However, the installation work may interrupt normal operations. There are cost factors which involve the time of installation. Understanding these issues, and addressing them in the Performance Contract, will go a long way to minimizing the risk to the end user.

Another key issue is operational in nature. Specifically, questions should be asked as to when and how the ECM will be installed and the potential impact on operations. Suppose the ECM is a fuel switch that requires a change in heating systems. If this ECM is to be installed during the heating season, then consideration must be given for "backup" heating. Additionally, adequate fuel supplies for the "new" fuel source could be an issue as well. It should not be assumed that the ESCo's proper addressing of all operation issues will automatically occur correctly. They should be specifically addressed in the contract as a means to minimize end user risk.

Another consideration is response to emergencies during construction by the ESCo. No one plans, expects, or wants an emergency, but the odds are that they will occur. What is important is to identify how an ESCo will respond to a potential problem. While not every contingency can be foreseen, it is important that the contract have provisions to minimize impact to any party.

FINANCIAL RISKS

The third area of concern is financial risk. The Energy Performance Contract has financial provisions in it regarding costs, contract length, savings, payments, terms, etc. The objective for all parties in contract negotiation is to insure that they fully understand the terms and conditions of the contract, and recover their costs at minimal risks.

The performance contract will have the following components:

- (1) The costs of the project
- (2) How these costs will be paid
- (3) Energy savings from the project
- (4) A termination clause.

The costs of the projects include all subcontractor materials and labor, engineering, sales, M&V, and an overhead and profit component. The true risk to the end user here is to understand how each component is developed and to insure that the costs are developed fairly, i.e., that he is not paying a high cost for the project.

There are numerous ways to finance a project and there are several excellent books and papers written on this subject. Some methods are fixed periodic payments, full sum at completion of construction, or shared savings. Each way has its pros and cons, and will not be discussed in this chapter. Suffice it to say that the end user should evaluate the proposed financial structure to insure that it minimizes his risks, and meets the financial guidelines of his company.

Determination of energy savings is an important subject. If there are no savings, why do the project? Energy savings should be subject to measurement and verification protocols (M&V). For purposes of this section, it is assumed that the M&V Protocol and Equipment is acceptable to the end user. Assume at this time that the energy savings that are presented are acceptable to the end user. Some contracts require that the end user share a percentage of these savings with the ESCo. Shared savings may be used to pay off the costs of the installed project, or may be used to pay for "further engineering services" related to the project, or both.

From an end user risk standpoint, there is an issue regarding what happens if projected savings are not realized, especially if the savings are

used in some fashion to pay off the installation costs. To this end, the end user should insure that he fully understands his risks involved with this and that he minimizes them. For example, the contract should hold the ESCo fully accountable for projected ECM savings as long as the ECM is operated according to standards defined in the contract. Likewise, the end user has some responsibility to insure that the ECM operates as he has agreed to in the contract. For example, if the ECM is a lighting retrofit, the ESCo should be accountable for the kW reduction of the retrofitted system as he designed it, and the end user insures that the hours of operation will be met. Either party should be culpable if their end of the project is not met.

The end user, however, should not accept unusual operational considerations of equipment under the new system. He should insure that his contract only requires him to operate the equipment as he normally would have, prior to the installation of the ECM.

To minimize the risk to the end user, clauses with potential penalties can be included, if under-performance of the ECM occurs not because of end user operational issues, but because of engineering design. This is especially important if the repayment of the project capital costs is dependent on energy savings. One way to insure this is to require that the ESCo provides a "guarantee" for the performance savings of the project. Typically, this means that the project will produce some mutually agreeable minimal savings during the course of the contract.

If the minimal savings is not achieved for a reason for which the ESCo is responsible, the ESCo must then pay a penalty to the end user. This type of clause is helpful especially in situations where minimum savings are needed to cover debt service for the project. There obviously is a cost to this, and the end user should be aware that his project costs will increase as a result of the guarantee. The "insurance" and the resulting peace of mind however, may be worth the cost.

Another key issue is increased savings due to over-performance of the ECM or an increase in energy prices. This becomes important in contracts which hold the ESCo responsible for under-performance. The ESCo will probably require, and I believe deservedly so, the rewards of over performance or increased energy prices. The fairest way is to share in this bonanza on a percentage basis. It then becomes a "win-win" situation for both the end user and the ESCo.

One issue frequently overlooked is maintenance and warranty issues. It is extremely important from an end user view to insure that he

fully understands his maintenance responsibilities over the life of the contract as well as the warranty issues involved with the installed equipment. No one expects that the equipment installed as part of the Performance Contract will always be fully functional over the life of the contract. The end user should be well aware of his responsibilities in both maintenance and warranty issues. This will minimize the end user's financial risk due to under-performance of energy savings.

The last important financial risk to the end user is termination. Performance contracts are written with a termination clause in order to protect the ESCo and the financial lender from harm if the project ceases to exist during the life of the contract. The end user should recognize that this is important to a project, and it is unreasonable to request that termination clauses be excluded from the contracts.

While I have seen exclusion of such clauses on very rare occasions, they have been for end users who are typically quite secure. The cost to the end user is quite high, that is, project costs are usually fully recovered in the first year or two of the project, and any revenue gained by the ESCo after that is pure profit. The end user should consider termination clauses when negotiating his contract, recognize their integral part of the process, and develop his risk potential before signing of the contract.

VERIFICATION RISKS

One important portion of performance contracting is the measurement & verification (M&V) protocol to be used in the project, and the equipment to be used to perform the M&V function. Too often, this function is performed as an afterthought, the last task done in the completion of the project, and usually with whatever funds remain to the project. Such a cavalier approach usually will not minimize risk in performance contracts. The end user can enhance minimization of his risks by understanding the M&V protocol and insuring that it is satisfactory to his needs and is properly installed and documented.

All energy performance contracts need a baseline energy usage determination. For each ECM this is the calculation of energy usage that would have been consumed prior to the retrofit. Typically, models have to be developed for the "pre-implementation" condition on weather or production sensitive ECMs.

It has been my experience that the baseline models should be de-

veloped early in the project. The reason for this early development is that the models need to be reviewed to insure that they accurately reflect conditions prior to the retrofit, and are adjusted accordingly. Too often, this step is done late in the project, sometimes when "verification" of the baseline cannot be determined since existing conditions no longer exist. The end user, in order to minimize his risks, should be active in developing and approving the baseline.

The next step in the M&V protocol is to decide how energy consumption after an ECM retrofit will be determined and how energy savings will be calculated from this data. If the project can support the cost, utility grade metering should be employed to measure the "post-implementation" energy consumption data. If costs cannot be supported by the project, and engineering calculations are required, then once again the end user should be very involved and have approval authority for these calculations.

It has been my experience that not only are the M&V considerations usually an afterthought, but too often the end user has no input into the process. As a result, the end user has greatly increased his risks for under-performance of the project and the inherent financial liabilities for this inaction.

A side issue regarding M&V protocol and equipment is the maintenance requirement of the M&V equipment. Like the equipment installed as part of the project, M&V equipment is also subject to maintenance requirements. The end user should be aware of whose responsibility it is for such maintenance.

It also has been my experience that while such equipment may be 95% functional, faulty sensors can give erroneous results. Someone should be examining this equipment on a full-time basis and be responsible for correcting any deficiencies. The contract that the end user will sign may or may not specifically address this issue, but failure of any M&V component which results in under-performance may provide a risk to the end user.

ESCO QUALIFICATION

The last risk for the end user is the selection of an ESCo to perform the project. There have been numerous articles written regarding this subject. The end user, to minimize his risks, should thoroughly evaluate

the ESCo that he would like to use. He should remember that he wants a true partnership in this situation.

The ESCo, as a company, should be evaluated for qualifications. I have seen articles written which suggest that only a national, or maybe even an international company, with decades of experience in the performance contracting business, should be considered. If that is the case, then there are only a few companies who meet those requirements, and I personally would challenge their unilateral capability. Most, if not all of these companies, are vendors of equipment who have one purpose, to sell their equipment, whether the peg fits into the hole or not.

There are several smaller ESCos who have not been around a long time, who may also be local, who are excellent companies to do business with. These companies should be given a fair chance for evaluation.

Some of the items that the end user should consider about such companies are their financial strength, technical qualifications, success in the business, and depth within the company.

Obviously, as the ESCo is interested in the end user's financial strength, the end user should likewise be interested in his ESCo's financial strength. Do they pay their bills on time? Are their contractors paid within reasonable time periods? Has a D&B been run on them, and is it satisfactory?

What are the technical qualifications of the ESCo involved? Have they proposed a complex mechanical project, but they have never done anything but lighting retrofits? What are the qualifications of the personnel who meet with end users? Are they technically qualified to discuss all aspects of the project? Are they financially qualified to discuss the project? Do they appear to have a team supporting them?

What is the ESCo's business success in performing projects similar to that being proposed? Are there references available? How have their relations with contractors and vendors been? What are the savings results from previously installed projects?

What is the depth of the ESCo's organization? Is there only one engineer involved or is the office fully staffed? What support can be provided by the ESCo during emergencies?

Finally, an ESCo should not be discarded just because they have never completed a similar project, or if they are fairly new in the field. The evaluation should however, be more thorough. The end user may want to consider the ESCo for an initial smaller project for evaluation purposes prior to selecting them for a more complex project.

CONCLUSIONS

This chapter presents some of the risks involved in doing Performance Contracting for energy projects, and reviews how an end user can minimize his risks. It is important to note that the end user is one party in the execution of such a contract. It is also important to note that a partnership agreement between all partners will go a long way to minimizing risk and conflict.

The end user should recognize that there are risks in the:

- (1) Engineering
- (2) Implementation
- (3) Financial
- (4) Verification
- (5) And ESCo selection phases of an Energy Performance Contract.

The end user should fully understand all the risks that are involved within each phase, understand how much risk he is willing to accept, and insure that he actively participates in contract negotiations to reduce his risk to an acceptable level.

Chapter 17

M&V Options— Which is the Best?

INTRODUCTION

Determining the post-retrofit results of an energy saving project is the greatest source of disagreement in the energy services and performance contracting business. This chapter was written to provide readers a basic introduction to measurement and verification and guide their efforts in ensuring that the results of a performance contract are appropriately and accurately measured and verified. This chapter will:

- explain what measurement & verification is, and
- provide recommendation for measurement and verification

The process of measurement and verification of the results of a retrofit project is a challenging endeavor and requires a relatively high level of HVAC and other building systems experience and insight and skill in reviewing contractor submittals and contract management in general. Readers lacking in experience in this technical specialty are encouraged attend performance contracting and M&V seminars and review the available literature, articles, etc. to further educate themselves. Another option would be to hire a consultant with the necessary expertise to perform the measurement and verification work.

Readers, as occurs occasionally throughout this book, are asked to forgive the author for covering material in a chapter that is covered elsewhere—in the interest of having chapters stand by themselves to a large extent by providing a contextual introduction.

WHAT IS “M&V” (MEASUREMENT & VERIFICATION)?

First of all, it must be stated that savings cannot be measured! The problem here is the fact that we are endeavoring to measure something that is no longer there. As a result, the task is a challenge at best. Considerable efforts have been made to define and organize the methods for establishing the value of the results of an energy saving project. Indeed, a small “industry” has sprouted up in attempts to deal with this issue. The Department of Energy (among others) has sponsored efforts to develop standards for determining the amount of energy saved by energy retrofit projects (and indirectly, the dollar value of the savings as well). This standard, originally released in mid-1996 is entitled the “North American Energy Measurement and Verification Protocol” (NEMVP). Another document, similar in nature, and intended to be compatible with the NEMVP, is the Federal Energy Management Program’s “Measurement and Verification (M&V) Guidelines for Federal Energy Projects.” Released in late 1997 was an updated version of the NEMVP entitled the “International Performance Measurement and Verification Protocol” (IPMVP). Because these documents are pretty “heavy” reading, it may be helpful for some readers to turn to Appendix II in the 1997 IPMVP which is an abbreviated manual on measurement and verification (largely taken from the FEMP Guidelines).

As defined in the NEMVP there were three principal ways or options to establish the quantity of energy saved by a project. With the 1997 IPMVP, a fourth option was also added. These Options are as follows:

- Option-A, or “partially measured retrofit isolation”—also referred to by some as “stipulated values/calculations” (generally including one-time or periodic measurements)
- Option-B, or “retrofit isolation”—also referred to by some as “measure-specific instrumentation & metering” (generally using continuous measurements)
- Option-C, or “utility-bill comparison/whole-building comparison” (using the utility company meter or a whole-building sub-meter as the measuring device)
- Option D, or “calibrated simulation” (using a simulation program as the “measuring” device)

Each of these approaches to the task are described below in the chronological order in which they came upon the scene, in order to make their current existence more understandable for those “tackling” M&V for the first time.

Option-C, Utility-Bill Comparison/Whole-Building Comparison

In the early days of the energy services industry, the standard method of determining the post-retrofit performance of a project was utility bill comparison. In fact, the very first model energy service agreements developed by Lane and Edson, P.C., under contract to the DOE in the very early 1980's included this method as the only method of determining project performance.

Utility bill comparison contrasts post-retrofit utility consumption, as invoiced by the utility company, to pre-retrofit consumption (otherwise known as the “baseline” period) and generally multiplies the difference in units of consumption by the then-current unit cost for each type of energy. For utility-company metered buildings, the utility bill is the raw data source. For multi-building complexes, individual building meters would need to be installed to monitor the energy use of the building in question. This can get somewhat involved if the buildings share heating and cooling sources, for example. This methodology also includes corrections for the effects of other variables such as weather, hours of occupancy, changes in the use of the facility, etc.

Option-A, Partially Measured

Retrofit Isolation/Stipulated Values/Calculations

As time passed the projects and the buildings in which they were installed became more complicated. It became clear that there were situations that just could not be handled with a total-building approach such as utility bill comparison. As a result, another method evolved, initially called “stipulated calculations” in the mid-1980's. In a lot of ways, this can be the simplest of the approaches. Interestingly, based upon informal discussions with various ESCo's, this methodology is very commonly used, primarily because of its simplicity.

This approach consists of establishing pre-determined and Owner-and-ESCo-agreed (or “stipulated”) values or precise formulas for the calculation of energy cost savings being achieved. In the case of a stipulated value, using lighting fixtures for example, a set number of watts are agreed by the parties to be saved by a particular lighting fixture retrofit

(say replacing a 100 watt incandescent lamp with a 32 watt compact fluorescent replacement unit). In addition, the parties also agree to a stipulated value for the annual operating hours for the fixture (say 8760 hours for a hallway fixture in a government office building). The determination of energy savings then is simply the watts saved per fixture, multiplied by the number of fixtures, and then multiplied by the stipulated hours per year—and never changes throughout the term of the contract. To arrive at cost savings, the units of energy saved are then multiplied by the cost of electricity (which is taken from the current rate schedules or utility invoices—as further discussed below). Similarly, stipulated *calculations* are formulas that have one or more variables which are measured (perhaps once, or periodically—say the final connected electrical load of a high efficiency motor) and other variables which are stipulated (say the hours of operation as recorded during the feasibility study). The calculation of energy cost savings is the difference between the original connected load and the new connected load, multiplied by the hours of operation, all of which is again multiplied by the cost of electricity. Note that while the NEMVP and the 1997 IPMVP allowed for essentially no measurements (such as in the case of lighting fixture retrofits, where a third-party “measurement” is stipulated as being acceptable to the parties), the 2000 IPMVP prohibits this.

In the case of a CFC chiller retrofit, stipulated calculations might consist of periodically measuring the performance of the chiller at a variety of different load percentages and then creating a power-at-load algorithm to which is then applied a stipulated annual load profile (which was probably established during the feasibility study and agreed to by the parties). In this case the performance of the chiller would need to be maintained by the performance contractor if they are to receive the anticipated savings for the improved chiller efficiency which they created.

Option-B, Retrofit Isolation/ECM-Specific Instrumentation

Finally, as the performance contracting industry and marketplace evolved further, some people felt that yet a more precise way of determining the energy cost savings needed to be created and what was initially often referred to as ECM-specific instrumentation was created. Under this concept of demonstrating energy cost savings, temperature sensors, event sensors, flow meters, power transducers, and other instruments are applied to the equipment or loads affected by the energy con-

servation measures. The data gathered by these devices is then manipulated and integrated by the building automation computer system or other computer (a data logger) to calculate the actual energy cost savings produced by individual energy conservation measures.

As regards an integrated chiller retrofit, under Option-B, the scenario might be that the annual load profile in ton-hours per month and the annual energy consumed by the chiller and its various auxiliaries is monitored and established as a baseline during the feasibility study. Once the retrofit is done, both the actual load (in ton-hours) and the chiller plant's total energy consumption (including perhaps a variable frequency drive chilled water pump) is measured continuously. If load reductions (say due to the addition of an outside air economizer) are created by the performance contractor, then the savings achieved would be the plant's present energy consumption subtracted from the baseline condition (with some possible adjustments for changes in weather, etc.). If load reductions were not a part of the performance contractors work, then the savings might be the reduction in energy use per ton-hour multiplied by the baseline load in ton-hours.

Energy Cost Savings

Unfortunately, the 2000 IPMVP, the 1997IPMVP and the old NEMVP do not deal directly with the issue of energy cost. This is a fairly complicated issue, particularly because the cost of on peak power continues to grow—and will likely continue to grow even further following more restructuring of the electric utility industry. This is even more important for chiller retrofit since air conditioning energy use tends to fall primarily in the on-peak period defined by most utility companies (for example, under Pacific Gas and Electric's E-19 Secondary rate tariff, the cost of on-peak air conditioning use, including demand charges, averages out to about 20 to 25 cents per kWh, against about 5 cents at night!—and this does not even include the EPS or Energy procurement Surcharge that was enacted by the PUC following the post-restructuring debacle of 2000/2001 which *increased* on-peak rates by as much as 150% on large-user rate schedules!).

As regards Option-C, Utility Bill Comparison, it has been traditional to simply use average unit cost to convert units of energy saved into dollars saved (or “avoided” actually—see comments below). Average unit cost is determined by dividing the total utility cost by the total energy units consumed during the billing period. To be more sensitive to

time-of-use rates, it has become fairly common to actually track the consumption during each time period (which of course leaves one with what to do if the structure of the rate schedules changes over time, like going from three time-of-use periods per day to four—what a thought that is!).

As regards Option-A, a number of alternates are possible. One is to simply use average unit cost. Another is to use a weighted average based upon the utility company's rate schedule and reasonable assumptions about the time patterns of energy use or savings. This can be done with a mildly sophisticated spreadsheet (e.g., ERA's *TOUCANS* program—see Appendix A).

As regards Option-B, a number of alternates are also possible. Again, one option is to simply use average unit cost. However, given the more rigorous nature of instrumented M&V, average unit cost seems really inappropriate in the face of such rigor. Another, again, is to use a weighted average based upon the utility company's rate schedule and reasonable assumptions about the time patterns of energy use or savings as mentioned above for Option B. Yet a third alternative is to "build" the rate schedule right into the monitoring system. For example, if a full-time monitoring system were integrated with a computer-based front end (perhaps a building automation system) and were calculating and integrating energy units saved in real time, the software operating this system could easily have the local utility company's rate schedule built into the calculation and produce real time dollar savings as well. Of course, any such system would need to be well documented and gather data in an open and "auditable" fashion so that both parties to the performance contract could review and verify the savings figures produced.

Unique M&V Terminology

Newcomers to the field of energy services and performance contracting may find themselves confused when encountering some of the terminology employed in the leading guidelines for determining the actual performance of a project (such as the FEMP M&V Guidelines or the IPMVP/NEMVP). Specifically, the definitions of the terms "energy savings" and "energy savings estimates" may be very confusing for the uninitiated.

First of all, the term "energy savings" is used to encompass many things that are not actually *energy* savings. This is because the term is used to refer to many of the things a performance contractor may do to

a building (demand control, cogeneration, thermal energy storage, fuel switching, etc.) that do not save energy, but principally affect the cost of the energy consumed. Indeed, some of these techniques (say ice storage) can actually *increase* the energy consumed in a facility, while producing a cost savings.

While an alternative term, “cost avoidance,” is popular in some circles and speaks more directly to what is actually taking place, the term “energy savings” has become, *de facto*, re-defined to refer to utility cost reductions achieved by virtually any means.

Furthermore, use of the term “energy savings estimates” is also confusing and potentially harmful (and is still embodied in the 2000 FEMP Guidelines). In the construction industry, the term “estimate” has traditionally been used to describe something that is done during the planning and development stages of a project (*before* the project is actually done), such as cost *estimates*, load *estimates*, and, in the case of energy retrofit, energy savings *estimates*. By contrast, once the project is underway, the industry has traditionally switched to different terminology to describe that which is happening or *has already happened*, such as financial *accounting*, project job cost *accounting*, or cost avoidance *accounting*. Without insulting intent, calling the post-retrofit results of a project an “estimate” is like calling your post-holiday-season bills, as they come due in January, just an “estimate” of what you owe. It therefore can be very confusing (particularly to newcomers to the field of energy services and performance contracting) to realize that the *de facto* vocabulary being used in certain of the protocols to describe the post retrofit performance of an energy retrofit project is the term “estimate”—particularly when the engineer performing the energy audit also refers to his projection of future energy savings as an “estimate.” Unfortunately the term “energy savings estimates” is used to indicate both the “before” and “after” in different places in the IPMVP/NEMVP/FEMP Guidelines. Replacement of the term “energy savings” with “cost avoidance” has been considered by the IPMVP Technical Committee, but has never been adopted for use in the protocol.

RECOMMENDATIONS FOR MEASUREMENT & VERIFICATION

Each of the approaches described above has its advantages and disadvantages. Interestingly enough, some people state very strongly

that one method or the other is the only “accurate” way to measure post-retrofit energy savings and that the other methods are bogus. The truth is that *they are all accurate, ...and they are all potentially bogus*. It all depends upon the circumstances of the facility, the types of retrofit being performed, the “stability” of the facility and the relationship between the parties. Because reasonable people can find reasonable ways to agree, all of these approaches can be made to work and they all have their shortcomings, as is discussed at great length in the references cited above. As an aid to readers, presented below is a synopsis analysis of the various methods and their relative merits, as well as discussion of other relevant M&V issues. For consistency, once again, they are presented in their historical order.

Option C, Utility Bill Comparison

A first glance, utility bill comparison may appear to be “foolproof.” After all, what could be simpler than to compare the bill before and after—the results are there for anyone to see. Indeed, upper (non-technical) management has been known to take exactly this point of view. However, a number of factors can influence this methodology, including changes in the use, occupancy, and operation of the facility, and changes in weather.

For example, should a tenant in a commercial office building decide to install a main-frame computer in their space they might well do it with the knowledge of the building owner (and are known to actually have done so), but without this fact being communicated to the energy services company. The result is an increase in the utility consumption in the building, and a decrease in the energy cost savings determined by utility bill comparison, *which has absolutely nothing to do with any energy conservation measures which may have been implemented by the energy services company*. This situation is generally viewed as a risk in the eyes of the energy services company and is one that an ESCo will likely seek to avoid if such uncontrolled changes are anticipated in a facility.

The principal advantages and disadvantages of this approach are shown in the table on the following page.

This methodology would generally find application in simple, single-use facilities, with stable histories of facility occupancy and use and energy consumption (such as office buildings). Simple or complex retrofits can be accommodated by this method. Facilities consisting of multiple buildings on a single utility meter (and which may not have

OPTION C

ADVANTAGES	DISADVANTAGES
Simple, small number of data sources, with resulting low cost to use/administer	The effects of energy conservation measures can be “masked” by unrelated changes in use and occupancy
Since savings come “right off the bill,” the figures are often considered more “real”	Adjustments for changes in facility use, weather, etc., can be complex and an administrative burden—extensive adjustments can make the figures appear “artificial” and therefore untrustworthy

sub-meters installed, particularly on the thermal side), may find scant use of this methodology. Where individual buildings are fully sub-metered (electric and thermal) or are separately metered by the utility, and the facility is relatively stable, both the Owner and the ESCo may find this a cost-effective and low-risk measurement and verification technique.

Those facilities electing to use utility bill comparison would do well to employ a commercially available software product, and one that embodies a “white box” rather than “black box” methodology. As used herein, a “white box” program means one that shows all the calculations and adjustments that are being performed so that the report can be audited by an independent third party. Such programs include FASER, Metrix and Utility Manager, among others.

Option A, Partially Measured Retrofit Isolation.

This approach requires that both parties possess both a high degree of confidence in the effectiveness of the chosen energy conservation measures to reduce energy use and confident knowledge of (and willingness to agree to stipulating) the annual hours of use of the systems/loads being retrofitted. Use of this methodology requires an ESCo that is willing to determine and document the existing conditions and examine and document their retrofit plans in considerable detail and Owner’s facility

staff willing and capable of participating in the feasibility study and carefully evaluating the results of the study. Independent consultants may be needed on the Owner's side of the table, for example, if facility staff is unavailable or lacking in the needed expertise.

The advantages and disadvantages of this approach are:

OPTION A

ADVANTAGES	DISADVANTAGES
Extremely simple—frequently the only variables are either stipulated or measured once at the completion of the installation—often these figures are more “real” than other methods, especially in a complex, unstable building environment and where simple, periodic measurements are made	Can work to reduce the motivation of the installing contractor to work carefully and accurately since “their work is done” once they get the facility staff to agree to the stipulation
Administrative costs are kept to a minimum	Savings figure are sometimes viewed as “artificial” or “unreal” if they are based on too many stipulations

This method would generally find use in facilities:

- with constantly changing occupancy or facility use which would “mask” or counterbalance the savings that would otherwise be shown by the use of utility bill comparison,
- where a wide variety of conservation measures are being employed (making instrumentation prohibitively expensive), but each only have a modest effect on the facility's total use of energy (and thereby easily “masked”), or
- where very complex retrofits are being employed (making instrumentation prohibitively expensive)

As mentioned above, this methodology finds itself in very wide use among many ESCo's on many projects. Because it does depend upon the parties to disclose considerable information and to operate in an atmosphere of considerable faith and trust, this faith and trust must be manifested by both sides, else an agreement cannot and should not be arrived upon. Acting in good faith, however, the parties can collaboratively examine and decide upon worthy retrofit work, agree on fairly simple and efficacious means of "proof" (e.g., before and after measurement of lighting panel load or chiller kW on a high temperature day, or a one-week monitoring and profiling of the kW draw of a variable flow/vfd chilled water pump). This allows them to focus their efforts on properly installing, commissioning and operating and maintaining the equipment and systems, instead of contending over the "counting of the beans" at the end of the project. Indeed, excessive reliance upon elaborate measurement and verification schemes instead of expending energy on project implementation can result in a very poor ESCo/Owner relationship and remorse and distress following project implementation.

Option B, Retrofit Isolation.

Factors that impact the effectiveness of this approach include the complexity of the energy conservation measures implemented, the accuracy and reliability of the instrumentation equipment, and the validity of the mathematical formulas used in the energy calculations. Advantages and disadvantages for this approach are shown in the table on the following page.

This methodology would generally find application in:

- process-intensive environments (where instrumentation is the only way to "prove" that the retrofit works and the retrofit involves only a few systems, e.g., a chiller plant only retrofit)
- large and/or expensive projects (e.g., variable volume conversion of a 200 HP air handling system) where the cost of the instrumentation (and associated data gathering, reduction and reporting) is relatively small due to economies of scale and/or the relative high cost of the retrofit work (simply put, it takes the same amount of instrumentation to monitor a 20 HP air handling system as a 200 HP system, yet the 200 HP system will produce 10 times the savings for the same amount of M&V cost), or

OPTION B

ADVANTAGES	DISADVANTAGES
Separates out the effect of ECM's from other changes in building use and occupancy	Very expensive except on the simplest of energy conservation measures—takes a big project to support the instrumentation cost (e.g., a 1,000-ton chiller plant v. a single 200-ton chiller)
Due to continuous direct figures are often considered power more “real” and/or more “accurate”	Requires considerable administrative measurement, cost avoidance man- to maintain, calibrate, and trouble- shoot the instrumentation and calculational software—again, only a larger project can reasonably support the cost
Data gathering and calculations are verifiable	Verification can be time consuming and costly

- projects where only a very small number of simple retrofit measures are replicated in great quantity (and only a representative sample will need to be instrumented—say, lighting controls in a large office building)
- projects where very authoritative accounting of the savings produced by the project is of paramount importance (for organizational or technical reasons, i.e., where upper management insists on “proof” of savings or say where the project is a “demonstration” project and added documentation of results is needed)

For example, the retrofitting of a sizable central chilled water plant (say 1,000 tons or more) might be just the place to employ extensive instrumentation since a large portion of the instrumentation will likely be needed to properly monitor and automate the plant anyway and the project can probably absorb the cost fairly easily.

Option D, Calibrated Simulation

This chapter will not address this option to any extent, and it is largely an academic concept and computer simulation is best used as a calculational tool to allow both parties to arrive at reasonable stipulations or make post-retrofit adjustments to the baseline as a result of changing circumstances on the project (such as a change in building occupancy).

The one place where a calibrated simulation might find unique and potentially valuable use is if an owner would like a performance contractor to invest in a building yet to be constructed, by funding energy-efficiency upgrades (say a thermal energy storage system). The energy use of the building can be modeled before the building is built, and it can be calibrated after the building is up and running. The cost avoidance produced by the investment in thermal energy storage could be reasonably established by running the calibrated model with and without the TES in operation. Readers are encouraged to read Chapters 6, 12 and the author's book "Computerized Building Energy Simulation" (see bibliography) if more insight into this option is desired.

Choosing a Methodology

As a practical matter, it is likely that Stipulated Calculations (Option "A") will continue to be the methodology of dominant choice. This is due to its relatively low cost, the fact that it tends to minimize time-consuming contention, and the fact that a well-prepared and well-documented energy audit (as strongly recommended by the author) will leave relatively little uncertainty regarding the likely effectiveness of the ECM's being pursued. Annual verification in such a case would primarily consist of verifying functional performance of the equipment (say, confirming that the variable flow pump does indeed track the system differential pressure and the speed varies as needed to support the system's cooling demand) and possibly repeating some instantaneous measurements (say to reconfirm chiller kW/ton, for example).

In a sense, the foregoing discussion of measurement and verification implies that a single option should be chosen for a given project. This is not necessarily the case. It is altogether reasonable to combine a variety of methods to account for the energy and cost savings achieved by a project. For one notable integrated retrofit project in the west, a mix of methodologies was combined, for example, as follows:

- For air handling unit retrofit, Option-A, *Stipulated Calculations was used*. Based upon calibrated computer simulation, hourly savings values (for cooling, heating and fan operation) were established for each month of the year for “hours off” (hourly savings achieved by turning the system off) and “hours on” (improvement in efficiency while system is in operation). These values were then multiplied by the reduction in run hours and the new run hours respectively, to determine the energy units saved.
- For lighting fixture retrofit, Option-A, *Stipulated Calculations was used*. The watts per fixture retrofit was stipulated and multiplied by the fixture count and the stipulated hours of operation to determine energy units saved.
- For chiller retrofit, Option-B, *ECM-Specific Instrumentation was used*. Chiller operating parameters were monitored continuously through the building automation system and entered into a formula that calculated the chiller savings achieved.
- For securing the steam distribution system in the summer months, Option-C, *Utility Bill Comparison was used*. For the summer months only, the gas use baseline, less the savings attributed to air handling unit savings was compared to the actual current utility bill for natural gas. The difference was the savings attributed to securing the steam distribution system.

When to Finalize the M&V Details

Finally, and perhaps most importantly, the methodology for determining the results of the project (the actual savings being achieved) *must* be defined in detail prior to executing the delivery order. Since the “rubber meets the road” in energy services at the point of determining the actual savings being achieved, this challenging part of the delivery order must really be done up front, not later when the “horses are out of the barn”—no matter how tempting it may be to put this off, say, until the project design is complete. The detailed feasibility study must include a project-specific M&V plan and must include the (sometimes excruciating) details of how the project is to be measured and verified. This will be particularly complex, for example, if Option “B” is employed for an integrated chiller plant retrofit that combines a number of interrelated retrofits, such as variable flow chilled water and variable air volume.

Other Issues

There are a few other things that it is wise to consider relating to M&V, including as discussed below:

- over-reliance on M&V (i.e., *not* putting all your “eggs” in the M&V “basket”)
- commissioning
- data sourcing
- double checking results
- adjustments for changes in end use
- measure interaction

Over-reliance on M&V. As mentioned herein, savings cannot actually be measured. As a result, it is a big mistake to put all your reliance on M&V as your first and last line of defense. Many projects suffer from the “Jurassic Park Syndrome” wherein the answer that is found is the answer that was expected (i.e., when tracking the dinosaurs that were released the computer software in the movie assumed that the female-only dinosaurs could not reproduce, and therefore looked only for the number that were released—and no more—whereas one species could transmute to the opposite sex, just as some frogs do, and then reproduce). All too often any data that would lead to an answer that is other than expected (like the project’s not working) is ignored, and not reported. As mentioned in the article entitled “How to Marry and ESCo” (appearing in the Fall 1995 issue of *Energy & Environmental Management*), we have found million dollar projects where none of the installed equipment actually worked, yet glowing monthly M&V reports were being submitted to the Owner each month! The best “guarantee” you can have is to work the *process* of developing the project, including:

- a detailed feasibility study
- Owner and ESCo select measures to implement
- detailed final design and Owner’s review
- managed installation
- start-up and commissioning

Commissioning

This last item in the list above is critically important. Savings cannot be achieved unless the installed equipment has the *potential* to produce savings, i.e., it must be working. A regular inspection and verification of equipment *function* is an essential part of any M&V program (and should be a precursor to final project acceptance).

Data Sourcing

It should be a standard practice that the source data be accessible by both the facility staff and the ESCo. This takes a number of forms. The machinery or apparatus recording pertinent data being fed into the M&V calculations should be something that the technical project manager on the facility side and the ESCo should have equal access to. In addition, the data that is uploaded should be shared with both parties, generally on a disk, and clearly labeled.

Double Checking Results

The machinery is used to “crunch” the numbers (say a spreadsheet), should be available to both parties, even if the ESCo needs to buy the facility a copy of the software for their use. While it’s good to have faith in the other side, the facility should occasionally check out the data and see if they get the same results as the ESCo. An honest ESCo won’t mind this at all and will welcome someone on the other side actually taking an interest. It may also be a good idea to have a disinterested third party involved in doing the checking. In this fashion egos can be side-stepped and the third party “expert’s” word may carry more weight with the officials who are in a position to act on the results (a not uncommon phenomenon in large organizations). This idea has even more merit if ECM-specific instrumentation is employed, as the in-house staff may not have the time to keep up with the extensive data reduction that is associated with such an M&V approach.

Adjustments for Changes in End Use

Assuming that a model of the facility has been used during the feasibility study and stipulated calculations are being used for M&V, then when a change in the end-use load occurs, the new end-use load can be re-modeled on both the original and the retrofitted facility models to show the impact on energy savings. This impact should then be *equitably* settled between the parties. It is good to keep in mind that being

fair to the other side is probably a good idea since these sort of “swords” can frequently cut both ways. Say a 24-hour load suddenly reduces to 12 hours because a program has left a facility unexpectedly. While it might seem fair to reduce the ESCo’s savings by half, they made the investment in the facility with the assurance that the “rug” was not going to be pulled out from underneath them. Conversely, when a 12-hour load suddenly becomes a 24-hour load, it is equally valid not to reward the ESCo with a doubling of savings. Putting “floors” and “caps” on adjustments of this sort is a sage idea for inclusion in the M&V plan, which is part of the energy services agreement or performance contract. In fact, for example, such adjustments may be excluded completely for Option-B, Stipulated Calculations (since hours of use, etc. are already stipulated), with only adjustments made in the event of failures of the ESCo-installed equipment.

Measure Interaction

In most cases, the interactive effects are generally fairly benign. For example, lighting retrofit will generally produce additional cooling savings in a range of 10 to 30% of the lighting savings (depending upon whether an outside air economizer is in use, the hours of use and whether or not the HVAC system is a mixing system—for terminal reheat HVAC, for example, there may be additional no cooling savings!). By contrast, for variable air volume, variable air flow and other “high powered” retrofits (these, for example, vary according to the cube of the load being served), it is wise to consider interactions carefully. A 10 or 20% change in load could possibly double the savings that could occur, say, from a variable volume retrofit.

CONCLUSIONS

While it is not possible to actually measure savings, reasonable people can agree to practical and simple ways to establish with a high level of certainty and confidence the actual results of the energy savings measures being installed. As is common in virtually any facility engineering and operations situation, keeping it simple will make life livable!

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Chapter 18

The M&V is Wrong... Now What Do You Do?

First of all, it's real important at this point to remember what measurement and verification is all about. While in itself it is a fairly complicated and involved topic and endeavor, at its essence it is very simple.

As a practical matter, it is often good to think of measurement and verification in exactly the reverse order than which it is usually referred to. That is, verification is perhaps the more important part and the one that should be done first in the process of doing measurement and verification.

In the process of verification, we literally verify that the retrofit project has the ability to produce savings (or as we prefer to refer to it, "cost avoidance," remembering that a 10 percent reduction in energy is concurrent with a 10 percent increase in the unit cost of energy, will produce no actual savings in a one million dollar utility bill, but will avoid an additional cost that would otherwise have been incurred).

In the process of verification we should be physically examining and observing the physical condition and function of the retrofit work. For example, on a variable air volume retrofit we should be observing that the digital control system is actually monitoring the duct static pressure, that the static pressure actually changes over time (as a result of the distribution box dampers performing their control function), and that the digital controls are actually slowing down the fan speed as duct static pressure rises, in order to reduce fan power consumption. Not uncommonly, this is done on an annual basis, or perhaps on a continuing basis.

The second part of the measurement and verification process is measurement, so as to, in one form or another, account for the energy

savings produced by a retrofit project. This may involve relatively simple and infrequent measurements, or, perhaps rather complex and continuous measurements.

One of the principal characteristics of measurement and verification is that it is potentially the most contentious part of a performance contract. It is literally “where the rubber meets the road.” It is incidentally also a fairly controversial topic in the industry and a source of expert testimony assignments for our firm. Viewing Figure 18-1, we can see that the simplistic concept of performance contracting and measurement verification is that energy use is relatively stable over time prior to the performance of the retrofit project. Assuming that all things are equal (i.e. no interfering changes have taken place), it is assumed that what took place in the past, i.e., stable and relatively constant energy use, would have continued into the future and after the retrofit is done the level of energy consumption is reduced and the difference between the pre-retrofit or “baseline” energy use and the post-retrofit, measured energy use is savings. Referring to Figure 18-2, we can see that if things are not equal, or interfering changes have taken place (such as the 3 percent annual “creep” or increase in electrical energy use such as we typically see in hospitals) then the post-retrofit energy use may also tend to rise and ultimately catch up with our supposedly stable baseline, thereby potentially “eliminating” our otherwise apparent savings.

SO... THE PROJECT DOESN'T WORK!

So, you’re a facility manager and you got management to do this new-fangled thing called performance contracting, but now it’s six months or a year or so after the fact and the truth is, the savings just aren’t there! What a jam you’re in, and you just don’t know what to do. Well, there’s actually quite a few things you can do (though you might want to get some expert help in the process).

In the following discussion, we will describe two scenarios, as follows:

1. A little shortfall, which generally means the project was probably pretty well done and needs to be addressed in the fashion referred to as “Plan A” below.

ALL THINGS BEING EQUAL.....

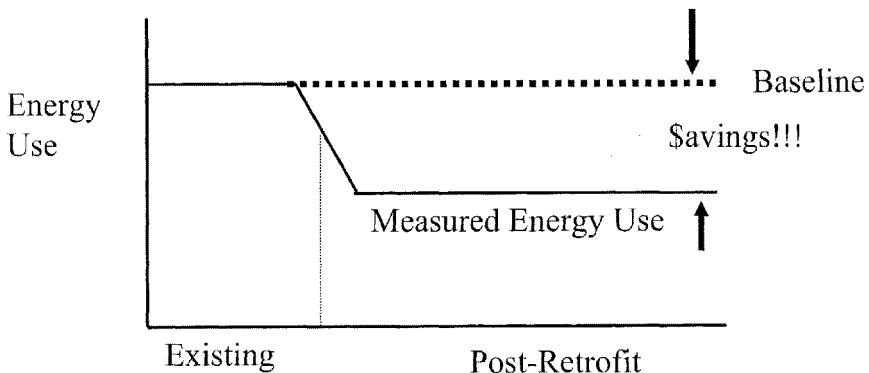


Figure 18-1.

BUT THEY AREN'T ALWAYS.....

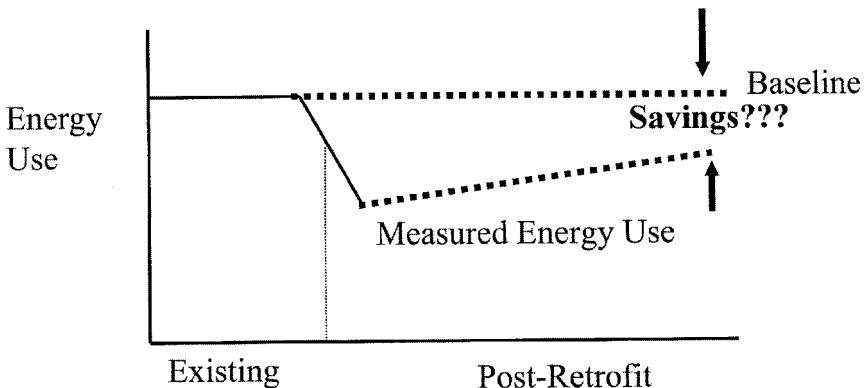


Figure 18-2

2. A big shortfall (perhaps *no savings at all*, as we have observed on actual projects) meaning that the project in the majority was ill-conceived and/or mismanaged, which will be addressed in the discussion below, entitled "Plan B."

PLAN A (A LITTLE SHORTFALL)

In the case of a small shortfall in savings, say, in the range of 10-30 percent less than predicted or guaranteed, a number of steps would be appropriate, including the following:

- The first thing to do is compare the engineer's projection of savings, by end use, with the documented savings. By "end use" we mean things such as air distribution (variable air volume conversion), cooling (such as a chiller retrofit), lighting, etc.
- Assuming Options A and B (which provide documentation measure-by-measure—sometimes referred to as "retrofit isolation") have been used for measurement verification, the M&V documentation can simply be compared to the original projection of savings (which was also hopefully been done measure-by-measure—see Chapter 5 on Investment Grade Audits). If the portion of the project that is not performing cannot be identified by this comparison, then the "verification" portion of M&V can be used to go out in the field and examine the various retrofit measures to determine which, if any, are no longer performing or are performing not as intended.
- The next step would be to fix or "tweak" those retrofit measures which are not performing by repairing failed control components, installing additional devices (say that chiller isolation valve that should have been part of the project but was inadvertently left off), or
- Negotiate an adjustment to the baseline, because, in the process, it has been discovered that the "plug" load in the building has doubled from 0.6 watts per square foot to 1.2 watts per square foot since the building baseline was established (as we observed on one 1.8 million-square-foot building in Texas), or
- Get out the checkbook and write the Owner a check to make up the difference in the missing savings (assuming instead that you are the ESCo)

Curiously enough, not that many years ago, one of the biggest names in the performance contracting business was known to allocate

fully 10 percent of their annual sales volume to make good on projects that had gone bad (of course, only on those projects where the owner actually noticed that there was a problem and actually complained)!

PLAN B (BIG SHORTFALL)

In this case, we're talking about a project that has seriously "gone south." As mentioned, we have audited large projects that weren't just producing ten or twenty or thirty or forty percent less savings than guaranteed, but *no savings at all!* In this case, an audit of the entire job from beginning to end is in order, including the following steps:

- The baseline. Was a baseline ever established? In one case, 18 months after the retrofit project was placed in operation, the very well nationally known performance contractor sent our firm an RFP requesting a flat fee (fixed price) proposal to *develop the baseline!* The project manager for this very large firm was mystified that we had not responded and couldn't fathom our response the we generally decline to step in front of the "ventilator" once the "fertilizer" is already in it.
- Examine the energy audit and its documentation. Was an investment-grade energy audit performed? Or was a sales engineer's "back-of-the envelope" estimate of savings the only actual "audit" performed. In one case we consulted on, the owner unfortunately signed a one-page audit agreement, agreeing to pay the performance contractor \$75,000 for a "detailed energy audit." Those three words were the entire specification for what was supposed to be an investment-grade energy audit. Our firm uses a seven-page standard to define the steps involved in an investment-grade energy audit. Somewhat not unsurprisingly, this particular owner (a school district) received a 36-page report in return for their \$75,000. Prudently, they did not accept the 36-page report, but then found themselves in a year-long "battle" trying to extract enough information from the performance contractor to be able to know whether or not they should sign a \$3,000,000 performance contract. Unfortunately, the performance contractor stated that "the reason we don't give our clients any detail is because they trust us." Astoundingly, this

performance contractor could not see the error of their ways, and actually ended up hurting themselves because, not only was the baseline not defined in any appropriate documentation for use by *either* side in the ongoing relationship, but, the ultimate sale of the three million dollar project was delayed for over a year and almost cost the sales engineer and the performance contracting sales manager their jobs. Perhaps not surprisingly, the sales manager later moved on to work for a very large Texas energy commodity and energy-services provider that later went out of business (you know who I mean).

- Next, the individual energy conservation measure that were proposed need to be examined for their reasonableness. Could they actually work? Unfortunately, at times, the salesmen exercise too great an amount of control over the process and incorporate measures into a project that their own engineers would reject, but for the fact that they cannot overpower their own company's salesmen (see Chapter 9).
- Examine the savings projections for each energy conservation measure as to their reasonableness. In one project examined, the sales engineer's audit counted cooling savings at the air handling units and then counted them once again at the chiller. Needless to say, if you measure the flow going in one end of a pipe and out the other end of the pipe, the total flow in the pipe is not the sum of both measurements.
- The guarantee should be examined for its reasonableness. In another project that we performed expert testimony work on, we discovered that the sales engineer substituted his own calculations for digital controls for the consulting engineer's estimate of savings derived from computer simulation. Unfortunately, because there were no "bounds" on the hand-done calculations, they were most optimistic and the sales engineer wrote into his contract a guarantee of \$150,000 per year savings in natural gas for a building that only used \$50,000 of natural gas in the baseline period! Astoundingly, this salesman's corporate headquarters were not astute enough to make even the most rudimentary judgment of the reasonableness of this guarantee by comparing it to the annual consumption of the facility.

- Examine the energy conservation measure designs for correctness. In one case, a performance contractor attempted to cut costs by combining a supply air reset point for both an interior and a perimeter air handling unit in a hospital. Now, while the interior air handling unit needed to provide cooling most of the time, the perimeter air handling unit needed to provide cooling when it was warm outside and heating when it was cold outside. Needless to say, the use of a single reset point could never have worked.
- Physically examine the energy conservation measures to see that they have been properly installed. This one speaks for itself, but for example, the addition of an outside air economizer to a building without simultaneously providing for building pressurization relief, will most likely ultimately result in the outside air economizer being overridden and disabled.
- Examine the energy conservation measures to see that they have been properly commissioned. In one case, we observed a variable flow chilled water system with the pump speed controlled by a pressure transmitter at the discharge of the main building chilled water pump. It takes a bit of knowledge of hydronic system design to understand that a *differential* pressure transmitter must be used and that this differential pressure transmitter must be located at or near the end of the distribution system in order to work.
- Examine whether or not the energy conservation measures have been maintained. In one case we discovered that the entire building automation system had been disabled due to a software problem and that the entire plant was operating in essentially a manual mode of operation.
- Examine the measurement and verification plan to see that it is sensible. Is the right information being gathered, and is it being processed properly? In one case we observed that supply air temperatures were being monitored in order to determine the energy units saved by means of supply air temperature reset. Unfortunately, this data was being inserted into a formula that was intended to receive units of enthalpy, not degrees Fahrenheit, and it was overstating the savings being produced by a factor of four.

The remediation under a “Plan B” disaster generally is going to take two courses, depending upon whether the flaws are fatal or non-fatal.

With fatal flaws, the ESCo will need to get out their checkbook and simply start writing the customer a big, fat check, possibly for every year of a multi-year contract. Undoubtedly, this performance contractor will also find it necessary to emulate the Queen of Hearts in the novel *Alice in Wonderland* in also recommending “off with their heads” with respect to the key project staff.

If the flaws are non-fatal, the project may be salvageable and may include modifying energy conservation measures to add controls or needed additional equipment, re-commissioning the energy conservation measures, redesigning the measurement and verification approach, or, if one is very lucky, renegotiating the deal with the owner. We have seen all of these done to good effect.

OUR RECOMMENDATIONS TO OWNERS:

Our recommendations to owners when considering and implementing performance contracting are short and simple, including the following:

- Only hire a performance contractor based on their qualifications. This is after all primarily a professional service, not a commodity.
- Insist on the use of detailed criteria for how *each part of the project* is to be implemented and documented.
- Manage the *entire* process and do not become an absentee owner.
- Stick to the basics and use your common sense, and remember... *there is no free lunch!*

Chapter 19

Show Me The Money

(Confessions of a Real Estate Property Manager)

Kevin Fraser, Fraser Limited

INTRODUCTION

I suppose my altruism is suspect, because when it comes to energy conservation I have to confess that I am not motivated by concern for the environment. Not that I am some rapacious strip-miner, just that after almost thirty years in the industry I've never seen a client spend hundreds of thousands of dollars on a system upgrade solely to help prevent global warming.

And lately I've noticed things have evolved even beyond that point, and come more directly to what I call bottom-line motivation.

CASH

You may say this is no revelation, but in fact it is, and the evolving energy retrofit industry is beginning to reflect this change in understanding. But let me first take things even a step further. I don't really care about saving energy either.

Heresy, I know, but think about it. If I want to get a project approved, I need to be worried about one thing—money. That's what sells the project, that's what gets things approved. The environment and benefit to the energy industry are just part of the bonus package.

And I mean to sell an energy project to a client if I'm a consultant or contractor. Sell a project to my boss if I'm a real estate manager. Sell a project to the execs if we own and occupy the building. Sell a project to the board if we hold investment property. All the same—money makes the decision.

PROOF: REBATE PROGRAMS

Obviously I am not alone in this thinking, and for evidence of this simply look at energy efficiency rebate programs. They all offer money. They don't offer a means to sidestep the building permit process, and they don't offer you an environmental credit so you can pour more waste into the neighborhood stream in exchange for using T-8 lighting (although Seattle does have a fascinating environmental credit program worth looking at). **The rebate comes right at the bottom line and they send you a check.**

And yet even here with rebates we often have a tough time selling the job, so what's wrong with the formula? Something else is playing other than simply money.

Somewhere along the line we need to redefine "cash." **Cash is not a discount. Cash is not a credit. Cash is not an on-going savings.**

Cash is CASH, good old green stuff you can spend anywhere, and this is essentially how things are changing.

Most efficiency upgrade projects offer the property something other than real money. And because of these rebate or performance structures, the offer is often declined, as it in fact will not benefit the building owner. This is key—it **does not benefit the person writing the check.**

"CASH IN THE BANK?"

Countless times I have listened to proposals detailing energy savings and performance, described as "cash in the bank." No—it isn't. "Good as cash." No—it isn't. "It's just like cash in your pocket!" No—it is not just like that. Otherwise, these projects would sell themselves.

For some rebate programs you first spend a lot of money doing engineering to design a project. There is no guarantee you will recover any of this money. Then you spend money doing the actual work, based on the promise that, if it performs, you will get some funding over a period of time. Then you spend money demonstrating the performance, and over a period of perhaps a few years you will receive a portion of the capital cost of the project.

BUT...

But that money may not reach your pocket. The property may have changed hands. The lease language may dictate that any such rebate go to the tenants, rather than to the landlord who performed the upgrade. Or the funding may come in the form of an on-going utility credit that would also benefit the tenants. Either way, the money comes back in a form that does not directly benefit whoever laid out the cash to begin with. And this also counts in owner-occupied structures.

And consider personal motivation. People change jobs, they change roles within a company, they move around. A project that may produce a rebate check in a few years isn't going to make you look good right now, but it may make the person who follows you look good when the money does arrive. Given your choice of projects to pursue, will you elect to focus on something with an immediate return, or an "iffy" future?

Sure, there are direct rebate programs where you get \$15 for every occupancy sensor you install, right up front when you show the receipt. **No proof of energy savings is required, and often not even any proof that you actually installed the devices.**

These are always the first energy conservation rebates to be approached each year, and then the funds are depleted, for just the reasons I have already stated. And these programs don't cover the type of big-ticket projects we all want to be involved with, such as new chiller plants.

Then comes the argument of doing upgrades for the sake of on-going energy/cost savings. We all know the pitch: If you use these light bulbs in place of your old ones, they will save you the cost of the project in two years, and provide a pure profit forever after. In fact this is true enough, but not many people care, again for some of the same reasons as above.

LIKE HOLLYWOOD...

Kind of like life in Hollywood—what have you done for me today (not tomorrow)? Additionally comes the problem that you can't consider your load as a fixed constant, but rather as a dynamic that will change

due to any number of influences.

So you effect changes that will reduce your load, and the company puts in a new telecom call center and the usage for the property goes up. Even though people know intuitively that what you did is a good thing, they don't see the savings and it gets tough to keep going back to the same cash well for future projects.

Again, given how fickle this is, where you would you focus your future attention? Cash. Not savings, not performance, not credit—cash, and now, not in the future.

This struck me recently because I have a large client who is doing energy retrofits across the country, on a \$15 billion portfolio. This client keeps bringing me hardware ideas from various vendors for consideration, and many of them are either snake oil or simply not a good application—at least in terms of savings. But I don't care.

I keep telling my client, "Let me tell them what kind of contract I want, and then who cares how the product performs!"

THE NEW BOTTOM LINE

And this is the new bottom line—show me the money. Don't tell me it will save me money; show me the money—**NOW**. Many vendors will guarantee a savings of 100 percent of 80 percent (*of the engineer's estimate, Ed.*), and in fact they get this performance underwritten by a third party insurer. So if a measure will save (in theory) 1000 kilowatts by design, they will guarantee that you will receive 80 percent of that in practice.

But here again we come to the demon of measurement and validation, and the long term return on the investment. Somebody has to babysit this operation and determine, in this minefield of variables, that indeed you are realizing the savings. And then if it is agreed that you are not gaining the stated advantage, you'll be paid the difference. But by now you are a year or more down the road and maybe you don't even own the property any longer.

Contractors are getting wise to this sales hurdle and are now finding ways, with much urging, to show the money up front where it counts.

Today in a performance contract I will look for the estimated savings derived by design, and will discuss with the vendor a guarantee period for performance; let's say five years. Then we will look for agree-

ment on a cost of energy across that period, allowing for increases in utility costs. This savings in energy, times period of performance, times the agreed cost of energy will give us a return value for the project in dollars. Now all we have to do is negotiate how much of that I can have up front.

Of course it won't be the 80 percent normally promised, and of course nobody gives away money. But it does pay for the project, and it does look good to the accountants.

WHAT ABOUT THE VENDOR?

So what does the vendor get for being out of pocket? A maintenance contract for the term of the performance guarantee. This is almost certainly a contract that would have been in place anyway, such as a service contract on air-conditioning equipment. And the argument goes that in order to assure performance, the contractor needs to have control of the maintenance of the system to assure it is operating at peak efficiency. And indeed, if they do perform this way, you will receive both the up-front money and a reduced cost of energy through lower consumption.

The only thing to watch out for is making sure you are not paying an unreasonable premium on the maintenance contract.

There is another approach, far easier and far faster, and this involves rebate funds. If a contractor states that their product is approved for any type of rebate funding, let them front the money. The best way to do this is establish the fixed price for the project, and then have them reduce the cost by the amount of the rebate. Then it is their responsibility (and problem) to acquire the rebate, which naturally they get to keep.

THE MONEY—UP FRONT

This is very attractive because it removes you from the hot seat of processing a lot of paperwork, managing a verification program, working with the utility, and possibly having the rug pulled out if funding does not come through. And—it shows you the money right up front where it counts, and where it is noticed.

I recently had a lighting contractor do this exact thing. They deter-

mined a retrofit to their lighting technology would be worth several thousands of dollars in rebates, and they removed this amount from the cost of the project, and took upon themselves the burden of acquiring the rebate.

It was wonderful! There was no smoke and mirrors, the numbers all played out, and the deal was real. Better yet—funding for the rebate program had not yet been approved by the utility/government and so there was some risk my client found unattractive. Now there was no risk at all—just pure up-front money.

Now when someone tells me they think this piece of equipment may not work, I ask, “So what?” The paperwork behind it is what counts. The deal I can cut with the vendor is what counts, We may not save the environment, and we may not realize a savings every month, but we have cash in our pocket and an improved property—let someone else worry if the product really saves energy. At least now I can get the projects approved, and the environment and ongoing savings are just part of the bonus program.

So don't come to me with all manner of glorious claims about how wonderful your product is and how much it will save me, all with no risk because it's such a great technology. Nope—show me the money. If you are that sure, then you take the risk and show me the benefit up front.

CASH.

Appendix A

Valuing Energy Savings

INTRODUCTION

The addition of this discussion on valuing energy savings is intended to correct a heretofore omission from the protocols, that of converting of units of energy saved into economic units saved, i.e., dollars.

This discussion will attempt in a modest fashion to correct that deficiency by addressing the following concepts and methodologies:

- “avoided cost”
- average unit cost
- weighted average unit cost
- calibrated simulation
- real time costing
- rate application

Readers should realize that, just as all methods of measurement and verification are imperfect, yet useful, the various methods of valuing energy savings presented herein are similarly flawed, but also useful as well

AVOIDED COST

Facility managers can get into trouble if they do not address the mind set of the “audience” they are working for—generally upper management. As a general observation, upper managers tend not to understand, nor do they particularly care about the intricacies of energy management and the “wonders” of the engineering world of Btu’s or

kilowatt hours. Rather, they more characteristically tend to think and deal in economic units, i.e., dollars. As a result, trouble can occur due to this difference in mind sets.

As a simple but illustrative example, suppose that the facility manager has managed to decrease energy use by 10% from the prior year. Unfortunately, however, the energy supplier has simultaneously raised his rates by 10%—with the result that the total cost of energy for the facility has remained the same. Now, suppose further that upper management, based on what they thought were the promises made by the facility manager for his energy conservation program, decreased the budget for energy by 10%—and has now discovered that they are 10% over budget. Upper management cannot help but conclude that the facility manager has failed to produce the promised “savings” (after all, they paid a million last year and the bill this year is still a million—meaning that there are no savings). The potential consequences for the facility manager are fairly obvious and ominous in this scenario—and would be avoided by any facility manager with any sense at all.

The astute facility manager, then, will have educated upper management in such a way that they understand that total energy cost is a product of two components, consumption and rates, and that further, cost may stay the same or even increase at the same time that “savings,” better known as “cost avoidance” is being achieved.

This “cost avoidance,” then, is the difference between what the actual cost of energy is versus what the cost of energy would have been had no conservation actions been taken. In our illustrative example, while total cost remained the same, it would have increased by 10% had no energy management program been implemented. This concept is particularly poignant in facilities such as acute care hospitals where a phenomenon known as “energy creep” is fairly common. In many acute care hospitals (and other types of complex facilities as well, of course), over time more and more diagnostic and other types of electric and electronic equipment is brought into the facility. When this is combined with the natural “wearing down” of the facility’s infrastructure systems (lighting, HVAC, etc.), it is not uncommon for a facility’s energy use to gradually rise over time. In one specific case documented in the references, a 10-year pattern of growing energy use was observed, approximately 3% for electric and 5% for natural gas, during a period where no active changes to the energy management program were undertaken.

AVERAGE UNIT COST

This is the simplest method of valuing units of energy, and may be applied to any of the 4 measurement & verification options (A thru D).

This method simply takes the total cost of energy (from the utility bill) and divides it by the total number of units consumed, thereby producing an average unit cost for the units consumed. To set a value for energy units saved, this average unit cost for the current period (typically a month) is simply multiplied by the units of energy the measurement and verification procedures identified as having been saved.

This method is obviously very simple and (perhaps obviously) ignores the fact that energy use often has a time-related value, as embodied for example in time-of-use (TOU) electric rates. Just as some believe that Option A in its simplest form (where few or no actual measurements are made) is a "bogus" M&V methodology, the use of average units costs may similarly be disparaged. However, if the energy management program being employed is a broad program that affects energy use in a generally uniform manner over all time periods, then it may well be a perfectly suitable and acceptable methodology to the parties to a performance contract.

WEIGHTED AVERAGE UNIT COST

This is a fairly simple method which is also applicable to all methods of measurement and verification. It is, however, perhaps best suited to Option A

This approach makes a number of thoughtful assumptions about the time-occurrence of energy use (or energy savings) and performs calculations which apply the appropriate rate schedules to the assumptions to determine a weighted average unit cost for the energy units

While it is based on assumptions, it may be updated or "calibrated" to actual experience if time-related energy use pattern data is available (say a 15 minute demand profile).

Tables A-1 through A-3 show three examples of a spreadsheet which performs the calculation of weighted average unit cost. Note

that the examples show three different patterns of energy use, and produce distinctly different results based on those patterns. Keeping in mind that the analysis assumes that the load being evaluated is a nominal 1 kW load, then the calculation of annual kWh, for example, also equals the equivalent full load operating hours (EFLH—please see the ASHRAE handbook for a discussion of this term if it is one with which the reader is unfamiliar). While a complete explanation of the details of the spreadsheet have not been provided, the majority, if not all, of the calculations can be understood by observation. The author will assist those in need of explanation as required.

REAL TIME COSTING

This method is a bit more rigorous than those discussed above, and is generally oriented towards Option B.

This approach consists of building the rate schedule into the monitoring “system” and apply the rate schedule “on the fly” as energy savings are (or were) actually occurring

For example, if a variable frequency drive was applied to a motor which previously operated fully loaded all the time, then the instrumentation, data gathering and data reduction measurement and verification “package” applied to this retrofit would, during each operating time window (perhaps an hour), measure the then-current energy use of the motor, compare it to the original or baseline energy use, calculate the energy units saved, and apply the rate schedule applicable during that window of time

If a real time system of data gathering and analysis is employed, then this valuing of energy units saved would also be in real time. However, the approach is just as effective in valuing the energy units saved even if it is applied after the fact to energy data gathered in real time, but analyzed at a later time.

Table A-4 shows a sample spreadsheet for an Option B measurement and verification of a variable volume fan conversion. In this example the baseline conditions have been established by short term monitoring of the fan motor and a load profile developed as well through short term monitoring and extrapolation to a year-long load profile by means of linear regression of the short term load monitoring data and applying the linear regression equation ($Y = mX + b$).

Table A-1. Average Electrical Cost Analysis (Based on time of use/savings)

TIME OF USE (TOU) GROUP:		1										DATE:		10/28/02						
DESCRIPTION:		24 HOUR ADAY OPERATION										INIT:		HK						
CALCULATIONS:																				
SEASON:	SUMMER	AVAIL.	OCC.	HRS																
(TOU)	—TIME—	HRS	HRS.	%	USE	PER	PER	PER	PER	PER	PER	PER	PER	HRS	KWH	TOTAL	**PEAK	**PART	**MAX	
PERIOD		DAY	DAY	IN	DAY	WEEK	SEASON	USE	COST	ENERGY	DEM	DEM	DEM							
OFF-PEAK	M/F	2400	830	8.5	8.5	x	100%	=	8.5	5	26.2	128	1088.0	\$0.05059	\$55.04	\$0	\$0.00	\$2.55		
PART-PEAK	M/F	830	1200	3.5	3.5	x	100%	=	3.5	5	26.2	128	448.0	\$0.05810	\$26.03	\$0	\$3.70	\$0.00		
PEAK	M/F	1200	1800	6	6	x	100%	=	6.0	5	26.2	128	788.0	\$0.08773	\$67.38	\$13.35	\$0.00	\$0.00		
PART-PEAK	M/F	1800	2130	3.5	3.5	x	100%	=	3.5	5	26.2	128	448.0	\$0.05810	\$26.03	\$0	\$0.00	\$0.00		
OFF-PEAK	M/F	2130	2400	2.5	2.5	x	100%	=	2.5	5	26.2	128	320.0	\$0.05059	\$16.19	\$0	\$0.00	\$0.00		
OFF-PEAK	S/S	0000	2400	24	24	x	100%	=	24	2	26.0	52	1248.0	\$0.05059	\$63.14	\$0	\$0.00	\$0.00		
OFF-PEAK	H	0000	2400	24	24	x	100%	=	24	N/A	N/A	3	72.0	\$0.05059	\$3.64	\$0	\$0.00	\$0.00		
SUMMER SEASON TOTALS														183	4392	\$257.44	\$80.10	\$22.20	\$15.30	
SEASON:	WINTER	AVAIL.	OCC.	HRS																
T	(TOU)	—TIME—	HRS	HRS.	%	USE	PER	HRS	KWH	TOTAL	**PEAK	**PART	**MAX							
PERIOD		DAY	DAY	IN	USE	DAY	WEEK	SEASON	USE	COST	ENERGY	DEM	DEM	DEM						
OFF-PEAK	M/F	2400	830	8.5	8.5	x	100%	=	8.5	5	26.0	125	1082.5	\$0.05038	\$53.53	\$0	\$0.00	\$2.55		
PART-PEAK	M/F	830	1200	3.5	3.5	x	100%	=	3.5	5	26.0	125	437.5	\$0.08392	\$27.97	\$0	\$3.85	\$0.00		
PART-PEAK	M/F	1200	1800	6	6	x	100%	=	6.0	5	26.0	125	750.0	\$0.06392	\$47.94	\$0	\$0.00	\$0.00		
PART-PEAK	M/F	1800	2130	3.5	3.5	x	100%	=	3.5	5	26.0	125	437.5	\$0.08392	\$27.97	\$0	\$0.00	\$0.00		
OFF-PEAK	M/F	2130	2400	2.5	2.5	x	100%	=	2.5	5	26.0	125	312.5	\$0.05038	\$15.74	\$0	\$0.00	\$0.00		
OFF-PEAK	S/S	0000	2400	24	24	x	100%	=	24	2	26.0	52	1248.0	\$0.05038	\$62.87	\$0	\$0.00	\$0.00		
OFF-PEAK	H	0000	2400	24	24	x	100%	=	24	N/A	N/A	5	120.0	\$0.05038	\$6.05	\$0	\$0.00	\$0.00		
WINTER SEASON TOTALS														182	4388	\$242.06	\$0.00	\$21.90	\$15.30	
ANNUAL TOTALS:														365	8780	\$499.51	\$80.10	\$44.10	\$30.60	
ACTUAL RATE SCHEDULE														RESULTS OF ANALYSIS						
RATE:	PG&E E19S	EFFECTIVE:	1/1/98																	
DEMAND CHARGES (per KW)	SUMMER	WINTER													TOTAL DEMAND (KW) COST:	\$155				
MAX. PEAK:	\$13.35	\$0.00													TOTAL ENERGY (KWH) COST:	\$500				
MAX PART-PEAK:	\$3.70	\$3.85													TOTAL COST:	\$654				
MAX DEMAND:	\$2.55	\$2.55													TOTAL COST/KWH:	\$0.075				
ENERGY CHARGES (per KWh)															AVERAGE COST/KWH W/O DEMAND:	\$0.057				
PEAK:	\$0.08773	\$0.00																		
PARTIAL-PEAK:	\$0.05810	\$0.06392																		
OFF-PEAK:	\$0.05059	\$0.05038																		

NOTES: * WEEKDAYS "DAYS PER SEASON" ARE LESS HOLIDAYS

** DEMAND COST SEASON SUB-TOTALS ARE FOR 6 MONTHS

1. ALL CALCULATIONS ASSUME A 1 KW LOAD

2. ALL DEMAND COSTS ARE "% IN USE" TIMES RATE IN EFFECT FOR PERIOD

3. COST CALCULATED HEREIN MAY BE USED FOR VALUING CONSUMPTION OR SAVINGS

Table A-2. Average Electrical Cost Analysis (Based on time of use/savings)

TIME OF USE (TOU) GROUP:		2 TYPICAL OFFICE USAGE FROM 7 A.M. TO 7 P.M.												DATE:		10/28/02			
DISCRIPTION:														INIT:		HK			
CALCULATIONS:																			
SEASON:	SUMMER	AVAIL.	OCC.	HRS OF USE												**PEAK	**PART	**MAX	
(TOU)	--TIME--	HRS	HRS.	%	PER	PER	IN	PER	PER	PER	PER	OF	UNIT	ENERGY	DEM	DEM	DEM		
PERIOD		DAY	DAY	USE	DAY	WEEK	SEASON	SEASON	SEASON	SEASON	USE	COST	COST	COST	COST	COST	COST		
OFF-PEAK	M/F	2400	630	8.5	1.5	x	100%	=	1.5	5	26.2	128	192.0	\$0.05059	\$9.71	\$0	\$0.00	\$2.55	
PART-PEAK	M/F	830	1200	3.5	3.5	x	100%	=	3.5	5	26.2	"	448.0	\$0.05810	\$26.03	\$0	\$3.70	\$0.00	
PEAK	M/F	1200	1800	6	6.0	x	100%	=	6.0	5	26.2	"	788.0	\$0.08773	\$67.38	\$13.35	\$0.00	\$0.00	
PART-PEAK	M/F	1800	2130	3.5	1.0	x	100%	=	1.0	5	26.2	"	128.0	\$0.05810	\$7.44	\$0	\$0.00	\$0.00	
OFF-PEAK	M/F	2130	2400	2.5	0.0	x	100%	=	0.0	5	26.2	"	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00	
OFF-PEAK	S/S	0000	2400	24	0.0	x	100%	=	0	2	28.0	52	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00	
OFF-PEAK	H	0000	2400	24	0.0	x	100%	=	0	N/A	N/A	3	0.0	\$0.05059	\$0.00	\$0	\$0.00	\$0.00	
SUMMER SEASON TOTALS														183	1536	\$110.56	\$80.10	\$22.20	\$15.30
SEASON:	WINTER	AVAIL.	OCC.	HRS OF USE								PER	PER	IN	PER	PER	**PEAK	**PART	**MAX
(TOU)	--TIME--	HRS	HRS.	%	PER	PER	IN	PER	PER	PER	PER	DAY	WEEK	SEASON	SEASON	SEASON	DEM	DEM	DEM
PERIOD		DAY	DAY	USE	DAY	WEEK	SEASON	SEASON	SEASON	SEASON	USE	COST	COST	COST	COST	COST	COST	COST	
OFF-PEAK	M/F	2400	630	8.5	1.5	x	100%	=	1.5	5	26.0	125	187.5	\$0.05038	\$9.45	\$0	\$0.00	\$2.55	
PART-PEAK	M/F	830	1200	3.5	3.5	x	100%	=	3.5	5	26.0	"	437.5	\$0.06392	\$27.97	\$0	\$3.65	\$0.00	
PART-PEAK	M/F	1200	1800	6	6.0	x	100%	=	6.0	5	26.0	"	750.0	\$0.08392	\$47.94	\$0	\$0.00	\$0.00	
PART-PEAK	M/F	1800	2130	3.5	1.0	x	100%	=	1.0	5	26.0	"	125.0	\$0.06392	\$7.99	\$0	\$0.00	\$0.00	
OFF-PEAK	M/F	2130	2400	2.5	0.0	x	100%	=	0.0	5	28.0	"	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00	
OFF-PEAK	S/S	0000	2400	24	0.0	x	100%	=	0	2	26.0	52	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00	
OFF-PEAK	H	0000	2400	24	0.0	x	100%	=	0	N/A	N/A	5	0.0	\$0.05038	\$0.00	\$0	\$0.00	\$0.00	
WINTER SEASON TOTALS														182	1500	\$93.34	\$0.00	\$21.90	\$15.30
ANNUAL TOTALS:														365	3036	\$203.80	\$80.10	\$44.10	\$30.80

ACTUAL RATE SCHEDULE

RATE: PG&E E19S EFFECTIVE: 1/1/98

RESULTS OF ANALYSIS

DEMAND CHARGES (per KW)

SUMMER

MAX. PEAK:

MAX PART-PEAK:

MAX DEMAND:

WINTER

\$0.00

\$3.65

\$2.55

TOTAL DEMAND (KW) COST:

\$155

TOTAL ENERGY (KWH) COST:

\$204

TOTAL COST:

\$359

ENERGY CHARGES (per KWh)

PEAK:

PARTIAL-PEAK:

OFF-PEAK:

\$0.00

\$0.06392

\$0.05038

TOTAL COST/KWH:

\$0.118

AVERAGE COST/KWH W/O DEMAND:

\$0.067

NOTES:

* WEEKDAYS "DAYS PER SEASON" ARE LESS HOLIDAYS

** DEMAND COST SEASON SUB-TOTALS ARE FOR 6 MONTHS

1. ALL CALCULATIONS ASSUME A 1 KW LOAD

2. ALL DEMAND COSTS ARE "% IN USE" TIMES RATE IN EFFECT FOR PERIOD

3. COST CALCULATED HEREIN MAY BE USED FOR VALUING CONSUMPTION OR SAVINGS

Table A-3. Average Electrical Cost Analysis (Based on time of use/savings)

ACTUAL RATE SCHEDULE			RESULTS OF ANALYSIS		
RATE:	PG&E E19S	EFFECTIVE:	1/1/98		
DEMAND CHARGES (per KW)	SUMMER	WINTER			
MAX. PEAK:	\$13.35	\$0.00		TOTAL DEMAND (KW) COST:	\$44
MAX. PART-PEAK:	\$3.70	\$3.65		TOTAL ENERGY (KWH) COST:	\$68
MAX DEMAND:	\$2.55	\$2.55		TOTAL COST:	\$112
ENERGY CHARGES (per KWh)				TOTAL COST/KWH:	\$0.088
PEAK:	\$0.08773	\$0.00		AVERAGE COST/KWH W/O DEMAND:	\$0.054
PARTIAL-PEAK:	\$0.05810	\$0.06392			
OFF-PEAK:	\$0.05059	\$0.05038			

NOTES: * WEEKDAYS "DAYS PER SEASON" ARE LESS HOLIDAYS

DEMAND COST SEASON SUB-TOTALS ARE FOR 6 MONTHS

1. ALL CALCULATIONS ASSUME A 1 KW LOAD.

1. ALL CALCULATIONS ASSUME A 1 KW LOAD
2. ALL DEMAND COSTS ARE % IN USE/TIMES RATE IN EFFECT FOR PERIOD

2. ALL DEMAND COSTS ARE % IN USE TIMES RATE IN EFFECT FOR PERIOD
3. GRT BALANCED HEREIN MAY BE USED FOR VALUING CONSUMPTION OR SAVINGS

Table A-4. VAV Cost Avoidance

DAY TYPE:

WEEKDAY

DATE:

COST:

06/09/98

RATE SCH

HOUR	EXISTING		RETROFIT		DELTA	DELTA	
	KW/KWH	KWH	KW/KWH	KWH	KWH	KWH	
1		\$10.12		52	\$2.62	148	\$7.50
2		\$10.12		50	\$2.51	150	\$7.61
3		\$10.12		44	\$2.25	156	\$7.87
4		\$10.12		41	\$2.09	159	\$8.03
5		\$10.12		38	\$1.94	162	\$8.18
6		\$10.12		40	\$2.05	160	\$8.07
7		\$10.12		54	\$2.72	146	\$7.40
8		\$11.62		69	\$3.99	131	\$7.63
9		\$11.62		88	\$5.09	112	\$6.55
10		\$11.62		103	\$5.96	97	\$5.66
11		\$11.62		113	\$6.55	87	\$5.07
12		\$11.62		127	\$7.39	73	\$4.23
13		\$17.55		148	\$13.01	52	\$4.53
14		\$17.55		161	\$14.11	39	\$3.44
15		\$17.55		170	\$14.95	30	\$2.66
16		\$17.55		173	\$15.20	27	\$2.34
17		\$17.55		170	\$14.95	30	\$2.66
18		\$17.55		161	\$14.16	39	\$3.37
19		\$11.62		141	\$8.19	59	\$3.47
20		\$11.62		119	\$6.89	81	\$4.71
21		\$11.62		100	\$5.82	100	\$5.82
22		\$10.12		85	\$4.28	115	\$5.82
23		\$10.12		74	\$3.73	126	\$6.31
24		\$10.12		65	\$3.27	135	\$6.81

TOTAL/AVG.

4800 \$299.42

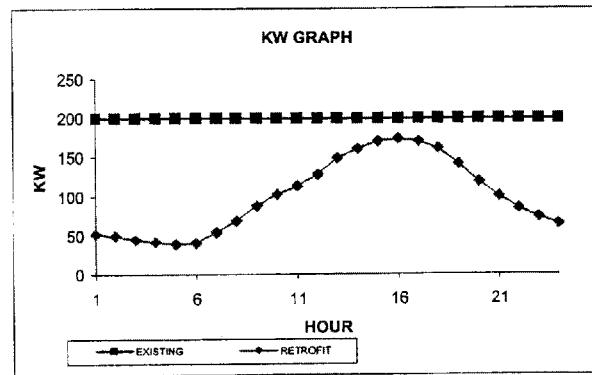
2386 \$163.7

2414

\$135.71

(Cont'd)

RATE SCHEDULE: PG&E E19S		EFFECTIVE DATE:	01/01/98
DEMAND CHARGES (per KW)	SUMMER	WINTER	
MAX PEAK:	\$13.35	\$0.00	
MAX PART PEAK:	\$3.70	\$3.65	
MAX DEMAND:	\$2.55	\$2.55	
ENERGY CHARGES:			
PEAK:	\$0.08773	\$0.00	
PARTIAL-PEAK:	\$0.05810	\$0.06392	
OFF-PEAK:	\$0.05059	\$0.05038	



RATE APPLICATION

This method has Option C in mind and assumes that either the utility meter is being employed to measure and record both baseline and post-retrofit energy use, or that a meter of similar character has been applied to the facility, and that the baseline energy use has been recorded in such a way that the present rate schedule can be applied to it. That is, the peak demand, and energy use in each of the time of use periods is available.

In this instance the current rate schedule is applied to the recorded energy use and the total cost calculated—for both the baseline and post-retrofit situations. The cost avoided is simply the difference between the two.

A wealth of proprietary software is already commercially available to implement this methodology, such Faser, Metrix and Utility Manager to name three.

CALIBRATED SIMULATION

This method is not for the faint of heart and is oriented towards Option D. This method, perhaps due to the extremely wide variation in simulation skill and acumen among its practitioners, has a reputation of being completely hypothetical, extremely effective, or anywhere in between.

Simply put, calibrated simulation requires significant rigor and clear demonstration of its faithful emulation of reality if it is to possess veracity. To achieve this goal, this approach would encompass, for example, the creation of a computer simulation model of a building or subsystem (say a chiller plant) in its baseline state, and the calibration (and demonstration thereof) of the model to reality. In addition, the retrofitted facility would also be modeled and calibrated as well. In the case of a chiller plant, the reality to which the models are calibrated might be a dedicated utility-style electric meter through which all power consumed by the plant is measured, and other specific measurements, perhaps instantaneous pump and cooling tower electrical demand, total cooling provided by the plant (ton hours output), etc.

Because both the baseline and retrofit conditions are simulated and calibrated, there can be considerable faith, then, in the veracity of the

units of energy and time-related patterns of energy use in the model.

Assuming that the simulation tool used for the modeling has the ability to incorporate and apply the rate schedules in use, then both models may be run with whatever current rate schedule is in effect, and very accurately calculate the cost of operation of the baseline and the retrofit facilities. Avoided cost, then, is simply the difference between the two.

CONCLUSION

The bottom line of all these efforts, again, is to translate the “technical” determination of units of energy saved into a financial result which management may make use of. Without doing so, energy engineers run the risk of being dismissed as being irrelevant by upper management, so this step in the M&V process is, perhaps amazingly, the one that may be the most important of all!

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Appendix B

Technical Bulletin: Estimating Chiller Load from Percent of Full Load Amperage

ERA TECHNICAL BULLETIN:Estimating Chiller Load From Percent of Full Load Amperage, Page 1

TECHNICAL BULLETIN:

ESTIMATING CHILLER LOAD FROM PERCENT OF FULL LOAD AMPERAGE

The following technical bulletin presents *ERA*'s findings and suggestions for estimating the load on a centrifugal chiller by means of measuring and interpreting the percent of full load amps the chiller is drawing.

1. BACKGROUND.

Due to *ERA*'s practice involving many variable flow chilled water conversions over the years and *ERA*'s practice of building and commissioning digital control systems for select clients, we have developed significant expertise in this arena. Accordingly, this technical bulletin has been written so as to more easily share our expertise in this area with those with whom we are collaborating. As noted below, this document is copyrighted and those not sent this bulletin directly by *ERA* should contact *ERA* for permission and possible payment of use fees.

In recent years it has become fairly common practice to employ variable flow chilled water systems in buildings and facilities. A confounding problem for some control and building automation system designers/installers is how to control the plant, specifically when to bring additional chillers on line as load increases, and when to take chillers off line as load is de-

ing (the “stage-up” and “stage-down” decisions). This is confounding because it has been strongly ingrained in the industry that chilled water systems are constant flow and that a multichiller plant can be controlled simply by watching the temperature of the chiller water returning to the plant, and when it starts to rise above an acceptable level, it means that more equipment must be put on line. The return water temperature may also be used to control the stage-down decision. Simply put, with variable flow systems, the temperature of the return water is very much unrelated to the load on the plant. In fact, when the load is light, the temperature is the highest -exactly the opposite of a constant flow system.

The simplest way to control a variable flow chilled water plant is to watch the load on the chillers and the plant in total. A properly sequenced chiller plant will result in no more than one start per day for each chiller in the plan. This can be accomplished if the actual load on the chiller is monitored by measuring chiller kW (or Amps if it is corrected for its non-linear relationship to kW) and a stage-up decision made when the on-line chiller(s) operate at more than 95% (adjustable for each stage) for a short time period (adjustable time period). A stagedown decision should be made when the total combined load of the on-line chiller(s) is less than approximately 80% (adjustable for each stage) of the next lower stage of capacity. For example, if two 300 ton chillers are operating, the stage-down decision would not be made until the total load on both chillers was less than approximately 240 tons. The problem with using temperatures is that they can fluctuate significantly over short periods of time and sensor inaccuracy, since there is such small room for error, can result in frequent cycling of chillers. We have seen plants where the chillers had more than 30 starts per days, which was eliminated when this control sequence was employed.

The purpose of this technical bulletin is revealed in the above comment... “or Amps if it is corrected for its non-linear relationship to kW.” The following comments will explain a methodology which ERA has developed to employ % full load amps as a method to estimate the load on a chiller. But first a few comments on why this might be a good idea.

- first of all, it is altogether possible that the instruments needed are already in place and can just be monitored through the building automation system running the plant
- relative to other instrumentation, current transformers are relatively cheap and easy to install—for example split-core CT’s are readily available and can be put in place without disrupting the existing electrical wiring

- watt transducers can be used and are relatively inexpensive as well, but even kW is not linear with load, so a reading from a watt transducer would have to be interpreted in similar fashion to a current reading
- directly measuring the actual load (in tons) is great, and so is watching all the control valve positions—but either of these require that a whole lot of instrumentation continue to function pretty darn well all the time - instead, using amps requires only one very simple instrument to work

2. SOME FUNDAMENTALS.

While the analysis provided below is relatively straightforward, it may be best to review a few of the fundamentals:

A. Chiller kW and Load.

If the performance data for chillers is examined closely, it can be observed that the part-load efficiency of centrifugal chillers varies a fair amount over its typical load range. Most chillers aren't real happy running at very low loads, and as a result generally find themselves running in the 30 to 100% load range most of the time. Examining the literature, we can see that the chillers get a bit more efficient as load drops off (kW/ton is less than nominal) and start to get less efficient as the low end of the load range approaches (at 10 to 15% the chiller may operate at 2 to 4 times its nominal kW per ton).

B. Power Factor and Induction Motors.

Power factor seems to be a relatively poorly understood electrical power issue. Apparent power is simply the product of volts and amps. However, in alternating current systems (such as most of the ones that power HVAC equipment), the timing of the sine wave patterns of voltage and current don't always perfectly coincide (known as out of phase) and it is this out of sync condition which makes real power different from apparent power. In fact, real power is the product of volts, amps and power factor (which is the Cosine of the phase angle, the out of sync angle, between the two sine waves, and varies in value from zero to one). Now it turns out that induction or squirrel cage motors are very prone to experience poor power factor, which drops off dramatically as the load on the motor

drops off. Smaller motors are particularly sensitive, but larger motors will also, for example, operate at a power factor of as little as 0.6 at 20% of rated load. What this means is that real power can be a whole lot different than apparent power! For fun, it can be very interesting to put a power factor meter on an elevator and watch the power factor jump all over the place (these motors run at very low load on the “down” cycle).

The implication of all this for this discussion, is that the current required to produce a given amount of power increases dramatically as the power factor declines. This means that a completely unloaded motor may show that it is drawing 30 to 40% of full load amps - even when it is doing no work. Using amperage, then, to determine the work being done, is not a straightforward task at all.

3. ANALYSIS AND DISCUSSION.

Readers are referred to the accompanying spreadsheet which provides all the information needed. Each portion of the spreadsheet is discussed in the following:

A. Motor Data.

The left side of the spreadsheet shows data for typical large horse-power motors. This data was taken from published literature and, to make the math a bit more simple, an exponential equation was written which mimics the empirical data very closely. This relationship between load and power factor are plotted in the graph at the lower left. As you will see, this data is used later in the analysis. As a point of interest, if you've lots of time and can actually test the motor you wish to monitor, actual measured data could be analyzed and substituted for the typical data shown (but then that's probably not the point, is it?).

B. Chiller Data.

The next portion of the spreadsheet shows data for typical large centrifugal chillers, employing some condenser water reset (which also makes a difference as well). Again, this was taken from one manufacturer's data, but is pretty typical of centrifugal chillers in general. The data was read directly from the manufacturer's chart showing % kW against % load. It is expressed also in terms of per-

cent of nominal kW/ton, both as a point of interest, and for later use. This is calculated by dividing % kW by % tons.

Next to this section is a table that will allow the actual chiller you are working on to be input to the spreadsheet and its data analyzed. In this section of the spreadsheet the calculations are as follows:

- “TONS” is calculated by multiplying % tons by the chiller capacity for the actual chiller
- “kW” is calculated by multiplying tons by “CHILLER kW/TON” and by “% NOMINAL kW/TON”
- “POWER FACTOR” is determined from the first portion of the spreadsheet (it actually uses the same exponential formula from that section, based on % kW)
- “AMPS” is calculated by dividing “kW” by 3 phases, 277 volts and “POWER FACTOR”
- “% FLA AMPS” is calculated by dividing “AMPS” by the maximum value for “AMPS”

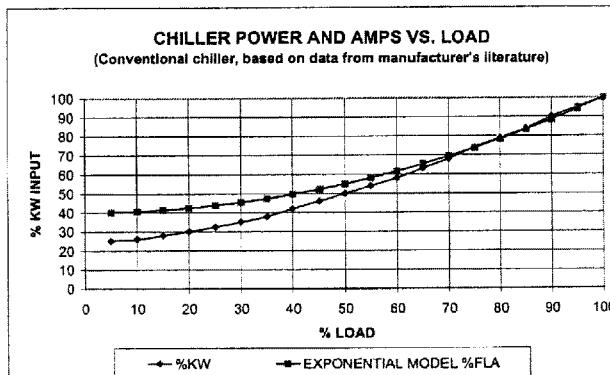
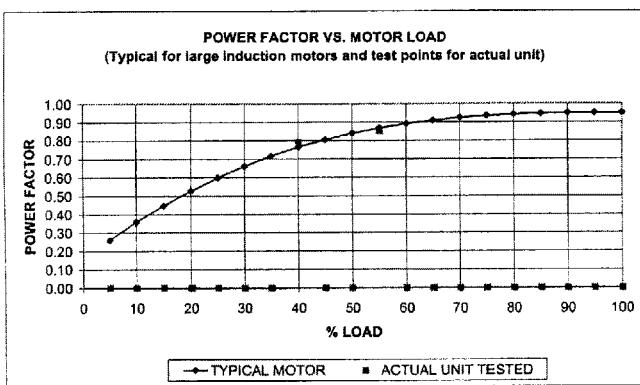
The next sub-section allows actual test data for the machine to be input, and then plotted on the first graph with the typical data if desired. Should the test points fall far off the “typical” curve, the assumed formula for power factor could be revised to thereby “calibrate” the model to the actual data. Caution is warranted here, as the form of the formula may need to be changed, and only if a goodly number of data points are gathered should this be attempted. After all, the whole point of this process is to find a quick, dirty, but pretty effective way to take a cheap instrument and actually exercise reasonable control over your chilled water plant.

C. Amperage Model.

The next portion of the spreadsheet shows the results of creating a simple exponential formula for modeling the chiller % full load amps at various load levels. The formula used is displayed on the spreadsheet as a footnote. In addition, the accuracy of the model is compared to the calculated values in the center of the spreadsheet which are based on typical motor and chiller performance empirical data.

-MOTOR DATA-		-CHILLER DATA-		-DATA FOR ACTUAL CHILLER-		-%FLA MODEL-		-%TONS MODEL-	
POWER FACTOR VS. % LOAD FROM TYPICAL MOTOR DATA	CHILLER % KW VS. % LOAD FROM TYPICAL CONSTANT SPEED CENTRIFUGAL CHILLERS	CHILLER CAPACITY = 535.00 TONS CHILLER KW/TON = 0.77				SEE FORMULA BELOW		SEE FORMULA BELOW	
EXPONENT = 2.85		TONS	KW	(INSERT P.F. & USE "TEST" GRAPH)	EXPOENT: 2.00	MODEL	WEIGHTED % TONS	MODEL	WEIGHTED % ERROR
% KW	P.F.	% TONS	UNIT % KW KW/TON	% TONS @ % NOMINAL KW/TON	POWER FACTOR	AMPS	% KW P.F.	% FLA	% ERROR
5	0.26	5	25	500	0.60	207	40	5	-5.0%
10	0.36	10	26	260	0.61	211	40	10	-1.5%
15	0.45	15	28	187	0.64	218	42	15	-2.3%
20	0.53	20	30	150	0.66	225	43	20	-0.3%
25	0.60	25	33	130	0.69	234	45	25	-0.6%
30	0.66	30	35	117	0.72	242	46	30	-0.7%
35	0.72	35	38	109	0.75	253	48	35	-0.8%
40	0.76	40	42	105	0.78	267	51	40	-1.2%
45	0.80	45	46	102	0.81	281	54	45	-1.4%
50	0.84	50	50	100	0.84	295	57	50	-1.4%
55	0.87	55	54	98	0.86	310	58	55	-2.0%
60	0.89	60	58	97	0.88	326	62	60	-0.8%
65	0.91	65	63	97	0.90	346	66	65	-0.9%
70	0.92	70	68	97	0.92	367	70	70	-0.9%
75	0.93	75	74	99	0.93	393	75	75	-1.6%
80	0.94	80	79	99	0.94	416	80	80	-1.4%
85	0.95	85	84	99	0.95	440	84	85	-1.0%
90	0.95	90	90	100	0.95	470	90	90	-1.5%
95	0.95	95	95	100	0.95	496	95	95	-0.8%
100	0.95	100	100	100	0.95	522	100	100	0.0%
FORMULAS:		$\%FLA = (0.4 + ((\%TONS/100)^EXPONENT)*0.8)*100$				AVG ERROR: -0.8% AVG ERROR: 1.4%			
$\% TONS = 100 * (((\%FLA/100)-0.4)/0.6)^{1/EXPONENT}$									

NOTE: %FLA/100-0.4 MUST BE A POSITIVE NUMBER



This is done to demonstrate that the simple exponential model is a generally faithful representation of the typical empirical data. As can be seen from the example, the rates of error are very small.

D. Tonnage Model.

The next portion of the spreadsheet shows the results of “reversing” the amperage model formula to create a simple exponential formula for modeling the chiller load in tons at various % full load amp levels. The formula used is displayed on the spreadsheet as a footnote. In addition, the accuracy of this simple model is also compared to the calculated values based on typical empirical data. As can be seen from the example, the rates of error are very small. Also of interest is the fact that the formula will produce negative values at very low load levels and therefore the formula needs to check for negative values as it intends to calculate the root of the number and there are few roots for negative numbers.

The use of the above data is to employ the tonnage model in a building automation system to measure % full load amps, and then estimate the chiller tonnage from it. While much “fine tuning” could be attempted, as a general rule, the formula can be used as-is for most centrifugal chillers and it will probably do a pretty good job, and allow reasonably accurate decisions for up and down staging to be made, as discussed above.

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Appendix C

Standards for Performing Energy Audit

I. SCOPE OF WORK

The energy audit shall be performed, as described below, for each of the Owner's Facilities.

- A. The ESCo shall obtain and review in detail existing documentation, as available, including:
 1. Utility company invoices
 2. Utility company demand interval recordings of 15/30 minute electrical demand for characteristic months of the year, where available
 3. Record drawings:
 - a. mechanical
 - b. plumbing
 - c. electrical
 - d. building automation and temperature controls
 - e. structural
 - f. architectural
 - g. modifications and remodels
 4. Original construction submittals and factory data (specifications, pump curves, etc.)
 5. Operating engineer logs, maintenance work orders, etc.
- B. Perform an inspection survey to:
 1. Identify the occupancy and use schedules. Interview the facility manager, chief engineer or others as needed.

2. Identify “process” energy use, such as, production equipment, computer rooms, printing plants, etc.)
3. Obtain the hours of operation for building systems and equipment.
4. Inspect major energy-using equipment, including:
 - a. Lighting
 - b. HVAC
 - c. Controls and automation
 - d. Other (process, outdoor lighting, etc.)
5. Compare the as-built configuration of the building systems (mechanical, electrical and architectural) for significant variation from the original construction documents.
6. Identify and characterize comfort or system-function problems which may impact the performance of the retrofit work
7. Perform “late-night” surveys outside of normal business hours or on weekends to confirm building system and occupancy schedules.

C. Prepare a post-inspection status report and provide to Owner, consisting of:

1. a list of energy retrofit opportunities which appear in the judgment of the ESCo to be likely to be cost effective and therefore warrant detailed analysis,
2. preliminary estimates of installation costs and energy cost savings for each Energy Conservation Measure option,
3. recommendations for terminating or continuing the Energy Audit if it appears unlikely that a project will meet the agreed upon cost avoidance commitment in Section 2B of the Energy Audit Agreement.

D. Survey major energy-using equipment. Record the following:

1. Equipment name-plate data
2. Identification name/number and/or description

E. Physically measure the peak electrical demand (in kW) of:

1. Major mechanical equipment (such as, pumps, fans, refrigeration machinery, equipment over 5 hp, etc.)
2. Lighting—where power distribution documentation and circuit segregation makes this feasible

- 3. Process and other significant miscellaneous loads
- 4. Instantaneous measurements shall encompass approximately 90% of the facility's total electrical load. Measurements of the entire facility and/or major feeders/risers may suffice where the in-facility electrical distribution is inadequately documented or where specific loads cannot be easily segregated.

- F. Continuously record the electrical demand of large and/or highly fluctuating loads over time to confirm their hours of operation and actual energy use. ESCo shall use its best judgment regarding the employment of instrumentation and recording durations so as to achieve an accurate and faithful characterization of the loads.
- G. Directly measure the operating parameters of mechanical systems and equipment as necessary for the analysis, to include:
 - 1. Air handling systems over 10,000 cfm (for smaller systems, name-plate or as-built data shall be used):
 - a. fan rpm
 - b. system static pressures
 - c. total air flow
 - d. outside air flow
 - e. system air temperatures (hot deck, cold deck, etc.)
 - 2. Wet side system water flows (or pump heads)
 - 3. Wet side system water temperatures
- H. Observe the function of the temperature controls under actual operating conditions and/or manipulate the controls as needed to confirm the actual sequence of control (and return to original settings).
- I. Tabulate the data gathered during the survey and process as required. Prepare in a format suitable for inclusion in the final report.
- J. Prepare a computer simulation model of the facility's annual energy use using DOE-2 or TRACE. Programs other than these must be approved by the Owner's project manager prior to their use. Calibrate the simulation model to actual energy use, within 5% for electrical and 10% for natural gas use. Demonstrate the model's calibration by providing a graphic comparison of the "base year"

and the “modeled” use showing monthly electric and gas use. Calibration shall have been demonstrated only when the characteristic shapes of the “base year” and “modeled” use are the same.

- K. Prepare detailed preliminary engineering for each ECM to include:
 1. A written description including:
 - a. the existing conditions
 - b. the changes to be made
 - c. the engineering principle(s) which create or cause energy to be saved
 2. A detailed scope of the construction work needed, suitable for cost estimating, including provisions for disposal and handling of hazardous materials
 3. Rough sizing of major equipment and a preliminary equipment selection list
 4. Layout sketches for complex chiller, boiler, piping, ductwork or other larger or complicated retrofits
- L. Prepare construction cost estimates. Submit cost estimates along with all backup, vendor and sub-contractor quotations and other supporting detail to the Project Manager for review. Cost estimates shall include special provisions, overtime, etc., as needed to accomplish the Work with minimum disruption to the operations of the facilities.
- M. For each ECM calculate the following:
 - a. base year energy use and cost,
 - b. post-retrofit energy use and cost,
 - c. percent cost-avoidance projected, by retrofit measure, for each
 - d. individual system or major piece of equipment.

Calculations shall:

1. Generally employ computer simulation. Simulation-prepared calculations shall be accompanied by a short explanation of the way the simulation program was used to accomplish the simulation of the retrofit and the key input data employed. Printouts shall be provided of all Input files and important

output files and shall be included in the Energy Audit. To assist reviewers, documentation shall be provided which explains how the final savings figures are derived from the simulation program output printouts

- 2. Manual calculations may be substituted where simulation is not feasible. If manual calculations are employed, formulas, assumptions and key data shall be stated.
- 3. Follow the methodology of ASHRAE or other nationally recognized authority and be based on the engineering principle(s) identified in the description of the retrofit option.
- 4. Provide an accounting for or explanation of how savings duplication between retrofit options is avoided.
- 5. Operational and maintenance savings, if any, shall be identified as a separate line item.

N. Prepare a preliminary measurement and verification plan, explaining how each Energy Conservation Measure, and each type of cost avoidance is to be measured and verified. This plan need only show intended methodologies, but is not required to identify precise instrumentation and/or formulae intended for use. This plan should be carefully enough prepared so as not to materially conflict with the final measurement and verification plan to be prepared during final negotiations of, and incorporated into, the Energy Services Agreement.

O. Prepare a proposed "Project Cost" and a list of "Services to be Provided," in anticipation of ESCo and Owner entering into an Energy Services Agreement to design, install, and monitor the ECM's proposed in the Energy Audit.

Project Cost is the total amount the Owner will pay for the Project. The Project Cost will compensate ESCo services desired by the Owner, which may include, but are not limited to: engineering, designing, packaging, procuring, installing, training, financing, and monitoring of the ECM's, and preparation of the Energy Audit.

The ESCo shall provide to Owner a list of services and the cost for each service, the sum of which shall equal the total Project Cost.

P. Meet with Owner to:

1. review the ECM options proposed in the Energy Audit, and assemble a package of options which is compatible with the Owner's investment and infrastructure improvement goals; and
2. review the proposed Project Cost and list of Services to be Provided to determine which further services Owner may want ESCo to provide.

Q. Provide to Owner a draft "Final Energy Audit" which shall include:

1. Body of the report:
 - a. introduction and summary,
 - b. a table summarizing the recommended ECM's, each ECM's design and construction cost, the first year cost avoidance (in dollars and energy units), and simple pay-back,
 - c. description of the existing facility, mechanical and electrical systems,
 - d. description of energy conservation measures, including estimated costs and savings for each,
 - e. discussion of measures considered but not investigated in detail,
 - f. conclusions and recommendations.
2. Supporting documents:
 - a. existing systems and equipment inventory / data,
 - b. tabulated survey measurements,
 - c. printout of simulation model of existing facility,
 - d. detailed scope of construction work,
 - e. cost estimates, including all detail and vendor and sub-contractors' quotes,
 - f. calculations used to determine estimates of energy cost savings,
 - g. preliminary measurement and verification plan,
 - h. a list of permits needed to implement proposed ECM's and any expenses Owner may incur in obtaining these permits,
 - i. "Statement of Proposed Project Cost and Services to be Provided."

- R. Meet with the Owner to present and discuss the draft Energy Audit.
- S. Revise Energy Audit as directed by Owner.
- T. Submit the final Energy Audit to Owner.

II. Technologies to Be Considered:

- A. At a minimum, the technologies listed below, shall be considered during the performance of preliminary feasibility assessments and detailed feasibility investigations. Should the engineer in responsible charge believe that a specific technology is either technically or economically unfeasible, this shall be discussed with the project manager and an agreement settled to either abandon or further investigate the technology. Any technologies so abandoned, shall have an explanation for abandoning the technology presented in the final report.
 - 1. Lighting fixture retrofit
 - 2. Lighting controls
 - 3. Building automation/digital controls
 - 4. Air handling systems:
 - a. variable volume conversion
 - b. constant volume airflow control
 - c. zone/area isolation & shutdown
 - d. air-to-air heat recovery
 - e. outside air economizer
 - f. return air conversion
 - 5. Plant/equipment modifications:
 - a. chiller upgrade/replacement
 - b. cooling tower upgrade/replacement
 - c. thermal energy storage
 - d. variable flow chilled water conversion
 - e. plant automation
 - f. boiler burner conversion/upgrade
 - g. boiler low pressure conversion
 - h. fuel switching
 - 6. Primary voltage power

7. Alternative power production

B. The following criteria establishes Owner's expectations and desires regarding the qualifications of engineers to perform feasibility studies and retrofit design. Engineers may be independent consultants or in-house engineers employed by the ESCo. ESCo shall submit engineers' qualifications for Owner's approval prior to commencement of any work. Once approved, ESCo shall use the same engineers throughout the project and shall not change engineers assigned to the project without Owner's written approval.

1. A registered professional engineer is preferred as the engineer in responsible charge.
2. The engineers should have extensive experience performing instrumented field surveys.
3. The engineers should have considerable computerized building simulation experience and expertise.
4. Engineers shall have worked for or with a design-build contractor, or at least have considerable experience at designing retrofit work.
5. Engineers should have a high degree of experience and expertise in digital and other control and automation systems. Engineer shall have designed control and automation systems as a member of a controls contracting company or independently.
6. Engineers should be able to demonstrate a track record of energy retrofit projects, with documented successful energy savings performance on facilities comparable to Owner's facilities.

Appendix D

ESPC Workbook

This workbook was prepared for the Federal Energy Management Program of the US Department of Energy. It is based on work by Andy Walker (National Renewable Energy Laboratory), Steve Kromer (Lawrence Berkeley National Laboratory) and George Blakey and Mark Stetz (Schiller Associates). Comments and suggestions should be forwarded to Steve Kromer, jskromer@lbl.gov. (510)486-6619.

INTRODUCTION

This workbook is designed to assist those involved with Energy Savings Performance Contracts (ESPCs) to quickly determine the viability of a particular project. By entering information about the costs of the project, the projected energy savings, and appropriate financial parameters, this workbook will calculate and display numeric information that will show whether the project will meet the federal guidelines, under EPACT. This workbook uses generalized financial calculations to approximate the actual costs of implementing an Energy Conservation Measure (ECM), but should not be taken to enumerate all the real costs of any such measure.

CONTENTS

The contents of this workbook are as follows:

- 1) Introduction—description of workbook; directions for use
- 2) Front Page—main entries; results displayed
- 3) Contractor's Costs—secondary entries; loadings calculated
- 4) Energy Savings—utility savings entries; total savings calculated

- 5) Debt—annual interest; payments and savings calculated
- 6) Retrofit Sample—example of projected savings from lighting retrofit

REQUIRED INFORMATION

You will need to have available the information listed below, in order to get the results desired. (See the section below titled Assumptions for clarification.)

- the cost of the project: the cost of materials and the cost of the labor.
- the projected savings of the project: the units of energy (e.g. kWh for electrical energy) projected to be saved, their costs per unit, and costs of other affected utilities.
- the change in the costs of the operation and maintenance (O&M) of the facility as a result of the implementation of the ECM;
- the estimated life of the components of the ECMs;
- the parameters affecting the margins to a contractor's base costs: profit, overhead, design cost program management, insurance, construction interest, and tax (these can be either in actual dollars or as a percentage of the project's base cost.)
- the interest rate and the term of the loan to finance the project;
- the current discount rate.

INSTRUCTIONS

The entry of data into this workbook is designed to be simple and straightforward. By using the tab key one can move the cursor around the individual pages, going to every area where an entry may be made. The user should begin on the *Front Page*. The top left section of this page is for the entry of the project's base cost, and the top right section shows the total projected savings for the ECMs. The bottom left section is where the various parameters are entered, and the bottom right section is where the results are displayed.

Some of the sections contain additional instructions for entering information on other pages of the workbook, depending on the data available. In all cases, the entered information will be blue in color.

The *Retrofit Example* page at the end of the workbook is for the user to see how the energy savings values can be calculated if the ECM includes a lighting retrofit. Some of the numbers in the chart can be changed in order for the user to see how a change of one variable will affect the results. None of the values on this page are linked to the other pages however, so any changes on this page will not affect the calculations or results of the project being analyzed.

All of the pages of this workbook will have values in place whenever it is opened for use. All of these values can be changed, if necessary. They can also be left in place for a preliminary analysis, until more accurate information becomes available.

ASSUMPTIONS

This workbook is intended as a preliminary screening tool for ESPC projects. The formulas and calculations used are designed to approximate the actual financial scenarios for the implementation of an ESPC, in order to see if the savings generated can justify the project's cost.

This version of the workbook does not include inflation factors in its calculations, so the annual savings and the annual payments figures will not be an exact picture of the proposed project's results, however they will be close enough to determine if a project is worth pursuing.

The build up of the margin elements are described next to each entry in the workbook. The equations for the margins are included for demonstration purposes only. It is easy to change the equations to reflect your actual margins.

Please send comments or questions about this spreadsheet to:

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Figure D-1. ESPC Workbook

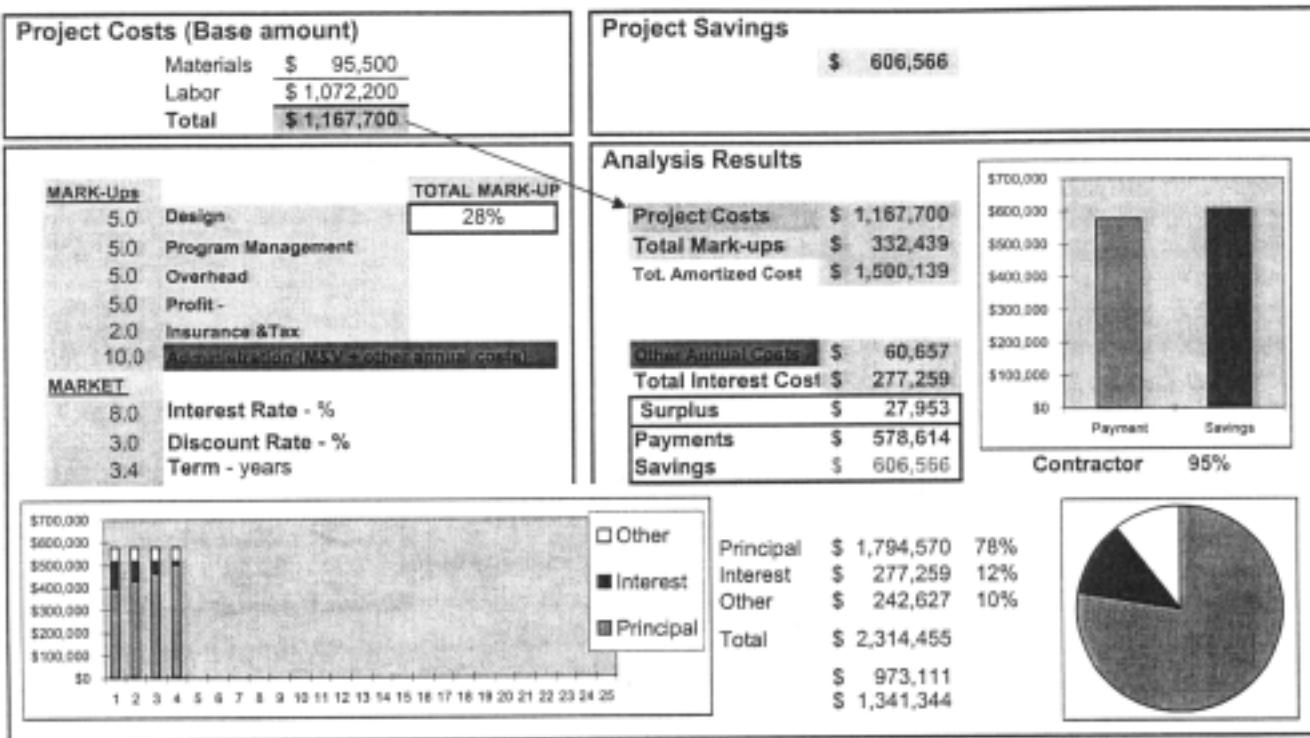


Figure D-2. ESPC Workbook—Retrofit Savings Example

IncluECM	Qty	Existing			Retrofit			Annual Demand	SAVINGS	COST		
		kWh/unit	Demand Hr/Yr	kWh/Yr	kWh/unit	Demand Factor	totkW	Hr/Yr	kWh/Yr	kWh	Hardware	Labor
X 1	5000	0.1	575	4,000	2,300,000	0.1	250.0	4,000	1,000,000	0	\$ 50,000	\$ 50,000
X 2	100	0.5	50	4,000	200,000	0.4	40.0	4,000	160,000	0	\$ 1,000	\$ 2,000
X 3	10	50.0	600	4,000	2,000,000	45.0	450.0	4,000	1,800,000	2	\$ 10,000	\$ 200
X 4	10	500.0	5000	4,000	20,000,000	250.0	1.0	2500.0	4,000	250	\$ 10,000,000	\$ 1,000,000
X 5	500	0.1	50	4,000	230,000	0.0	1.0	5.0	4,000	0	\$ 10,000	\$ 10,000
X 6	500	0.1	50	4,000	230,000	0.1	1.0	33.3	4,000	0	\$ 14,500	\$ 10,000
	6120	6240	24,960,000		3278.3		13113000			11,847,000	\$ 95,500	\$ 1,072,200
		Demand Savings Factor=>	0.2									
		Demand Savings	592.4									
								TOTAL		11,847,000		\$ 1,167,700

Note: Hardware and Labor costs from Means data -

Unit	ECM 1	Labor	\$ 10.00
COSTS	Lights	Hardware	\$ 10.00
	ECM2	Labor	\$ 20.00
	Motor	Hardware	\$ 10.00
	ECM3	Labor	\$ 20.00
	Motor	Hardware	\$ 1,000.00
	ECM4	Labor	\$ 100,000.00
	Chiller	Hardware	\$ 1,000.00
	ECMS	Labor	\$ 20.00
	Ext Sigr	Hardware	\$ 20.00
	ECM6	Labor	\$ 20.00
	Misc	Hardware	\$ 20.00

TOTAL	Energy SAVINGS	Demand Savings	Simple Payback
\$ 100,000.00	\$ 65,000.00		1.5
\$ 3,000	\$ 2,000.00		1.5
\$ 10,200	\$ 10,000.00		1.0
\$ 1,010,000	\$ 500,000.00		2.0
\$ 20,000	\$ 10,000.00		1.9
\$ 24,500	\$ 4,850.00		5.1
\$ 1,167,700.00	\$ 592,350.00		2.0

Figure D-3. ESPC Workbook—Contractor Cost Calculations

Materials	\$ 95,500		
Labor	\$ 1,072,200		
Total Base Cost	\$ 1,167,700	0.0	
Markups			
Design	58,385	5.00%	of base cost
Program Manage.	58,385	5.00%	of base cost
Overhead	64,224	5.00%	of base + design + prog. manage. costs
Profit	67,435	5.00%	of base + design + prog. manage. + overhead costs
Insurance	23,354	2.00%	of base cost
Construct. Interest	-	0.00%	of base + design + prog. manage. + overhead costs
Subtotal	\$ 271,782		
M&V	\$ 60,657	10.00%	of energy savings
Total Margins	\$ 332,439		
Total Project Cost	\$ 1,500,139		

Figure D-4. ESPC Workbook—Energy Savings Chart

This page will calculate the financial savings due to energy conservation of a given ECM. Energy savings as a function of season and time-of-use need to be known for a specific project.* Utility costs (including rate structures) also need to be known. Do not use dollar signs or commas when entering values.

* Electricity		Rate Structure		Energy Savings		Financial Savings
		\$/kW	\$/kWh	kW	kWh	
Winter	Full Peak	\$ -	\$ -	-	-	\$ -
	Part Peak	\$ 6.00	\$ 0.050	-	-	\$ -
	Off Peak	\$ 5.00	\$ 0.030	-	-	\$ -
Summer	Full Peak	\$ 9.00	\$ 0.040	-	-	\$ -
	Part Peak	\$ 7.00	\$ 0.030	-	-	\$ -
	Off Peak	\$ 5.00	\$ 0.030	-	-	\$ -
Average		\$ 2.00	\$ 0.050	592	11,847,000	\$ 606,566
Electric Savings Subtotal						\$ 606,566
** Non-Electric Utilities		Rate Structure		Energy Savings		Savings
	Gas	\$ 3.00	\$/therm	-	therms	\$ -
	Steam	\$ 3.00	\$/100 lb	-	100 lbs	\$ -
	Coal	\$ 30.00	\$/ton	-	tons	\$ -
	Other	\$ 1.00	\$/therm	-	therms	\$ -
	Water	\$ 1.16	\$/kgal.	-	kgallons	\$ -
Non-Electric Savings Subtotal						\$ -
Annual O&M Savings						\$ -
Total Annual Savings						\$ 606,566

* If only average kW and kWh prices are known, enter them on the Average line.

** If gas or steam consumption increases due to fuel switching, enter the increase as a negative number.

Figure D-5. ESPC Workbook—Debt and Cash Flow

Loan Term	3.4 years	Percent of savings
Project Lifetime	20 years	for Contractor payment
Interest Rate (%)	8.00	0
Annual Savings	\$ 606,566	4.5

Note: The loan starts in year zero and finances all costs. There is no Contractor Equity.

\$2,314,455

Contractor should provide interest rates in disclosure (required for sole-source)

Construction interest is included on the contractor costs sheet

Amount of loan is amount financed plus first year interest since payments don't start until the following year.

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