A new MVP perspective – Striking a balance between energy and cost savings and improving the indoor environmental quality in energy efficiency projects

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1. SYNOPSIS

Policy and technical issues pertaining to indoor environmental quality and overall building performance in energy efficiency projects are explored.

2. ABSTRACT

The International Performance Measurement & Verification Protocol[1] (MVP) has been widely used for determining savings in energy savings performance contracts (ESPCs) in the United States and efforts are underway for its international adoption as well. The latest edition of the MVP, which came out in January 2001 is a product based on extensive feedback from the users of the document. It provides a range of techniques starting from simple engineering calculations based on stipulations and measured data to sophisticated calibrated simulations and addresses the crucial issue of cost-effective M&V based on the requirements of individual projects.

The larger objective of the protocol is to promote investments in the field of energy services by providing a framework that can be used for credible and cost-effective energy savings estimates, which can then be verified by measured data. The latest update also addresses the issue of performance of the building energy system and its impact on the indoor environmental quality (IEQ) of buildings. A retrofit project offers tremendous opportunities for improving IEQ and the total building performance. While it is easy to get caught up in proposing innovative ways of third party financing, it is also important to keep in mind the importance of good indoor environment. Sometimes, focussing exclusively on energy savings and return on investments while ignoring the building performance issues may in the end prove counter productive and fuel continued scepticism towards the energy services industry. This paper will discuss the close linkages between the end use energy consumption and IEQ, the barriers currently facing the industry to bundle energy savings with improved building performance, and some new practical approaches that can help to address this problem.

3. INTRODUCTION

The building sector accounts for approximately one-third of the total energy consumption in developed countries with the balance used in the industrial and transportation sectors. As the condition of the existing building stock deteriorates, people look for innovative solutions to upgrade ageing facilities to satisfy the enhanced comfort requirements of people around the world. When looked upon as a global phenomenon, this continuous upgrading process requires a huge capital investment but also offers a tremendous opportunity to retrofit the existing infrastructure with the recent technological advances in the field of building technologies. This can help in providing comfortable living and working indoor environment through energy efficient systems.

The MVP was conceived as a vehicle to attract private sector money into capital-intensive energy efficient projects by developing industry-consensus methodologies for measuring and verifying estimated energy savings (Kats *et al.* 1997). The early development of the protocol was largely shaped by the regulations that were passed in the US in

1992 (Energy Policy Act, 1992) that guaranteed savings to federal agencies entering into "Energy Savings Performance Contracts" with Energy Service Companies (ESCOs). The ESPCs were conceived as a vehicle to reduce a) the energy use; b) the associated greenhouse gas emissions in federal facilities; and c) the operations and maintenance (O&M) costs using capital infusion from the private sector. This has worked as a catalyst for the growth of the performance contracting industry and the rise of energy service companies (ESCOs) who frequently rely on recovering their investments by reducing energy consumption in facilities. The MVP has played a vital role in creating a secondary market for energy efficiency in the US and to some extent internationally as ESCOs and financial institutions investing in these energy efficiency projects grew confident of the standard methods that can be applied across a variety of energy efficiency measures (Arney et al. 1998, Kats *et al.* 1997, NOVEM BV 1999).

Volume I of the MVP – *Concepts and Options for Determining Savings* (US Department of Energy, 2001a), which was published in January 2001 defines basic terminology useful in the M&V field. It revises the four M&V options detailed in the 1997 version of the protocol (US Department of Energy, 1997). Emphasis is also placed on developing a good M&V plan to be used as the basis for verification of savings. Volume II of the MVP – *Concepts and Practices for Improving Indoor Environmental Quality* (US Department of Energy, 2001b), which was published along with Volume I reviews indoor environmental quality issues as they may be influenced by an energy efficiency project. It focuses on measurement issues and project design and implementation practices associated with maintaining acceptable indoor conditions under an energy efficiency project, while advising on key related elements of M&V and energy performance contracts.

It can be argued that future energy prices and increased awareness about the indoor environment may combine to determine the clauses of the performance contracts that will be signed in future. While it is impossible to predict the directions in which the energy services industry will move in the years to come, it is possible that based on recent developments, a whole range of solutions including energy outsourcing, performance contracts, and chauffage[2] may be offered in future. The parameters that determine the quality of the indoor environment will acquire additional importance in such a scenario. The intention of this paper is to focus on Volume II – especially on the opportunities in any energy efficiency project that can help improve the indoor environment while saving energy – and the role that the MVP can play in achieving these twin objectives.

The need for a new paradigm

The construction industry is one of the most litigious industries in today's world. The total number of actors involved in a new construction or a retrofit project makes it an extremely arduous task to enforce performance specifications and hold people responsible for not fulfilling their contractual obligations. Quite often, the reasons for the failure or under performance of a system can be attributed to many factors, making it difficult to pinpoint the culprit in the building/system delivery chain. It is unthinkable to expect components in a typical building to meet the sort of standard that are fairly common in say, the aircraft manufacturing industry. While it is a matter of life and death if a part fails or under performs in an aircraft, the consequences are never so dire in the case of building systems except in the case of structural failure of buildings. Because the least cost approach is practised widely in the construction industry, conventional business practices often tend to ignore many systems level issues thereby introducing a lot of inefficiencies that could have been eliminated (Hitchcock *et al.* 1998).

Construction of new buildings offers an excellent opportunity to incorporate energy efficient and sustainable technologies in the design and construction of these buildings. New rating systems such as the US Green Building Council's Leadership in Energy and Environmental Design (LEED) (US Green Building Council, 2000) and Building Research Establishment Environmental Assessment Method (BREEAM)[3] are encouraging developments that are going beyond energy efficiency and putting a lot of emphasis on total building performance. However, more needs to be done to improve the performance of the existing buildings that far outnumber new buildings. The performance of existing buildings can be facilitated by adopting an integrated systems approach during retrofit projects that focuses on total building performance through integrated design, commissioning, and other quality control checks.

Creating alternative financing mechanisms to improve the energy efficiency of existing buildings has proved to be an effective policy tool in the United States federal sector. For example, in the year 1999, 21 projects were awarded in the federal sector that resulted in ESCO investment worth USD 65 million or approximately EUR 72 million[4] (Federal Energy Management Program, 1999).

However, as the MVP has matured, there is a growing perception that energy savings cannot remain the only issue. It is critical that the current model with its heavy emphasis on energy savings be refined to include methodologies that would enhance building performance by identifying the opportunities that present themselves during any retrofit project. Moreover, the process should be refined in a manner that does not place an undue burden on the energy service companies and at the same time educates the recipients of these services to utilise the opportunities to improve the overall building performance.

For example, a systems approach to the design of an energy efficient HVAC system would pay close attention to the efficiency of various components that constitute the whole system starting from the generation of steam or chilled water to the distribution of air by fans through the ducts to the delivery and mixing of air in the spaces occupied by people. The dependencies and relationships between these components and how the entire system reacts to the changing comfort requirements of the people are also equally important. The design approach must also consider the following factors during the design and construction of the systems. The following factors must also be considered:

- Thermal Factors: Air temperature, mean radiant temperature, and relative humidity requirements governing thermal comfort on the indoor environment side together with sensible and latent loads that directly affect energy consumption.

- Indoor Pollutants: Ventilation rate, pressure relationships, air filtration controlling the concentrations of pollutants but also affecting energy consumption.

These were the drivers that convinced the MVP management team to make a foray into the indoor environment even though it was not one of the core issues when the MVP movement was started in early 1994. The main reasons behind addressing these issues as part of the International Performance Measurement & Verification Protocol are listed below:

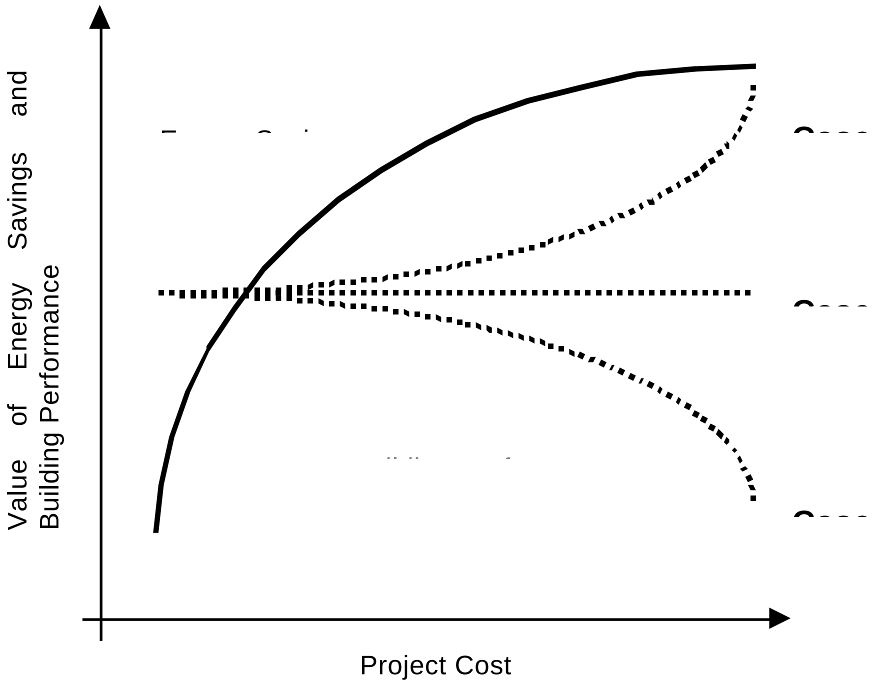
- Many building energy conservation measures have the potential to positively or negatively affect indoor pollutant concentrations, thermal comfort conditions, and lighting quality.

- Focusing narrowly on energy savings without paying proper attention to building performance is often a case of lost opportunity, as major retrofits are often costly and rare in a building life cycle.

- Energy savings numbers are prone to engineering creativity if energy savings contracts focus just on saving energy and do not pay enough attention to comply with existing indoor environment standards on lighting, thermal comfort, and indoor air quality.

Figure 1 shows the three scenarios that are possible after the implementation of an energy conservation measure. It depicts the relationships between the energy efficiency and return on investment requirement of a project on one hand, and its impact on total building performance including the indoor environmental quality. The intent of the MVP is to educate people about the importance of the total building performance and the indoor environmental quality while performing upgrades to their facilities so that they are in a position to extract maximum benefit from the project.

Figure 1. Possible scenarios in an energy retrofit project



Links between energy conservation measures and IEQ

Many characteristics of the indoor environment may influence comfort, health, satisfaction, and productivity of building occupants. The following indoor environmental characteristics are most likely to be influenced by building energy conservation measures:

1. Indoor thermal conditions such as air temperature and its vertical gradient, mean radiant temperature, air velocity, and humidity;
2. Concentrations of pollutants and odours in indoor air and amount of pollutants on surfaces;
3. Lighting intensity and quality.

The following table is extracted from Volume II of the MVP. It lists only those energy conservation measures (ECMs) that can significantly influence the IEQ of buildings and also suggests some of the precautions or mitigation strategies that can be put in place to avoid serious problems. References to publications have been removed from the excerpt and readers are encouraged to obtain a copy of the original document to get all the details.

Energy Conservation Measure	**Potential Influence on Indoor Environmental Quality (IEQ)**	**IEQ Precautions or Mitigation**
Energy efficient lamps, ballasts, fixtures.	Improved lighting quality is common if lighting system is properly designed and installed.	Emphasise lighting quality in design. Check lighting levels and reflected images in VDT screens. Provide task lighting. Ensure that lighting retrofits do not result in disturbance and release of asbestos, fiberglass, or irritating dusts.
Heat recovery from exhausted ventilation air or other source of waste heat.	If heat recovery system allows increase in rate of outside air supply, IEQ will usually be improved. Some heat recovery systems transfer moisture or pollutants from exhaust to supply airstream.	See outside air economiser discussion related to outdoor air pollutants. Ensure that heat recovery system does not transfer unwanted moisture or pollutants to supply airstream.
Use of outside economiser[5] for free cooling.	Generally, IEQ will improve due to the increase in average ventilation rate. During periods of elevated outdoor pollutant concentrations, economiser use may increase indoor concentrations of outdoor pollutants. In humid climates, economiser use may increase indoor humidity and the potential moisture-related IEQ problems.	Locate outside air intakes as far as practical from strong sources of pollutants such as vehicle exhausts, HVAC exhausts, and trash storage. If outdoor air is highly polluted with particles, use high efficiency air filters. Design and control HVAC economiser to prevent moisture problems. Economiser controls and associated minimum outside airflow rates should be regularly calibrated and maintained.
Nighttime pre-cooling using outdoor air.	Nighttime ventilation may result in decreased indoor concentrations of indoor-generated pollutants when occupants arrive at work. Nighttime ventilation with humid air may result in condensation on HVAC equipment or building components increasing the risk of growth of micro-organisms.	Design and operate nighttime ventilation systems to prevent moisture problems. Often, controls prevent nighttime cooling when outdoor dew-point temperature is excessive.
Use of variable air volume (VAV) ventilation system in place of constant volume system.	Risk of insufficient outside air supply when indoor cooling or heating loads are low. Particularly in HVAC systems with fixed outside air fraction, risk of excessive cooling and thermal discomfort when cooling loads are low if minimum outside air supply is maintained and supply air temperature is not increased. Increased risk of thermal comfort problems from supply air dumping[6].	Maintain outside air intake into air handler at or above minimum requirement for all supply airflow rates. Avoid VAV control units that close fully when space temperatures are satisfied. Supply air temperatures may need to be increased when cooling loads are low. Check total and local outside air supply and indoor temperatures for a range of cooling loads. Use supply registers, minimum supply flow rates and temperatures that do not cause supply air dumping and thermal discomfort.
Increase supply air temperature when cooling space (may decrease chiller energy but increase fan energy).	Higher supply air temperatures in VAV ventilation systems will increase supply airflow rates. In many VAV systems, outside airflow rates will also increase leading to reduced concentrations of indoor-generated air pollutants. Increasing chilled water temperatures often results in higher indoor humidity.	Maintain chilled water temperatures sufficiently low for control of indoor humidity.

Energy Conservation Measure	Potential Influence on Indoor Environmental Quality (IEQ)	IEQ Precautions or Mitigation
Thermally efficient windows.	Improvements in thermal comfort possible from reductions of drafts and reduced radiant heat exchange between occupants and windows. Reduces risk of condensation on windows and associated risks from growth of micro-organisms. Thermally efficient windows help to isolate the indoor space from outdoor sounds.	Not Applicable.
Use of natural ventilation with operable windows as a substitute for air conditioning.	In some climates, thermal acceptance of environment may increase because occupants in naturally ventilated buildings are tolerant of a wider range of thermal conditions. Thermal comfort may decrease because of elevated indoor temperature and humidity. On average, occupants of buildings with natural ventilation and operable windows report fewer acute non-specific health symptoms.	Building design, e.g., size, layout, openings for outside air, position of openings, and shading must assure adequate natural ventilation and thermal conditions throughout building. Generally, cross-ventilation is desirable. Occupant -controllable fans can enhance thermal comfort. Openable windows should not be located near concentrated outdoor sources of pollutants or annoying sounds.
Displacement ventilation (Displacement ventilation systems usually supply 100% outside air with improved IEQ as the main goal. The addition of heat recovery system may be necessary to achieve energy savings relative to some other methods of HVAC).	Generally, concentrations of indoor-generated air pollutants at breathing zone are reduced. Reduced transport of pollutants from sources to other rooms. Reduced risk of thermal drafts. Increased risk of thermal discomfort due to large vertical gradients in air temperature. Potential increased indoor concentrations of pollutants from outdoors, especially pollutants like ozone and particles that react with or deposit on indoor surfaces.	See outside air economiser discussion related to outdoor air pollutants. Design and operate displacement ventilation systems to avoid drafts in vicinity of supply diffusers and to avoid excessive gradients in air temperature. Displacement ventilation, without radiant cooling panels, may be effective only with internal heat generation less than 40 W m^{-2}.

What's in it for the ESCOs: Barriers and incentives

One of the biggest barriers to incorporating building performance improvement specifications in energy efficiency measures is the cost implication on energy retrofit projects. Most energy efficiency projects rely on a combination of engineering calculations, stipulations of key parameters based on historical and measured data, to calculate estimated energy savings. It is evident that in order to achieve improved building performance in a retrofit project, monitoring and verification not only of energy variables but also indoor environmental parameters will be required, which would increase the cost of the project.

A related issue is the notion of tangible benefits when adopting an integrated approach towards improving the building performance. While energy is a quantity that can be easily metered, improved building performance is often reflected in more subjective measures such as improvements in the performance, productivity, and satisfaction of workers. It is unreasonable to expect ESCOs to deliver better indoor environment as part of an energy saving performance contract (ESPC) unless there are incentives and checks that are also part of the contract. This can happen under the following circumstances:

- If the client is well educated about the benefits of better indoor environment and is willing to pay a premium for that service.
- Various standards require that minimum indoor environmental conditions be met whenever a modification is made to an existing facility.

One of the strongest arguments in favour of better indoor environment was put forward by Fisk and Rosenfeld (Fisk and Rosenfeld, 1997), who estimated that potential health benefits and productivity gains from improved indoor environments in the US are in the range of USD 17 to 48 billion as shown in the table below which is excerpted from that paper:

Source of Productivity Gain	**Potential Annual Health Benefits**	**Potential U.S. Annual Savings or Productivity Gain (1996 $U.S.)**
Reduced respiratory disease	16 to 37 million avoided cases of common cold or influenza	USD 6 – 14 billion (EUR 6.65 – 15.51 billion)
Reduced allergies and asthma	8% to 25% decrease in symptoms within 53 million allergy sufferers and 17 million asthmatics	USD 1 – 4 billion (EUR 1.1 – 4.4 billion)
Reduced sick building syndrome symptoms	20% to 50% reduction in SBS health symptoms experienced frequently at work by approximately 15 million workers	USD 10 – 30 billion (EUR 11 – 33 billion)

Under normal conditions if the investments made in improving the building performance cannot be recovered in a reasonable period of time, or in other words, are not cost-effective then any profit-making enterprise would refrain from investing capital in such projects. Under normal circumstances, contracts are written in such a manner that the emphasis is on saving money by reducing energy cost and many times the environmental conditions suffer because temperature setpoints, relative humidity setpoints, illuminance levels etc. are not required to be measured before and after the project. Although most projects have provisions to meet the minimum performance levels for the indoor thermal and lighting requirements, ESCOs are rarely required to conduct measurements to ensure that the conditions are indeed met[7]. It is extremely important that provisions be made to measure (before and after the implementation of the ECM) the relevant parameters. This is possible if the term "performance" is not narrowly defined in terms of energy savings and the incentive and penalty clause is also linked to the indoor environmental conditions in the contract.

It requires a greater commitment on the part of the client and the service provider to enter into an agreement that goes beyond energy savings. For the service provider, it means a greater level of expertise, a slightly more risky project, and the possibility of less than 100% satisfied customer. For the client, it means a willingness to spend more money than what would have been required in a conventional project, and the possibility of dealing with workers/employees who may not approve of the changes taking place in the building. It is, therefore, even more important that the two parties work closely together because of the challenges faced by both the parties. However, if implemented correctly, the project can deliver promised energy savings and also provide an indoor environment that is better than before.

It is important to note here that although this paper has primarily dwelt on the quantitative parts of energy efficiency projects, there are qualitative issues such as certain behavioural aspects of both occupants and facility operators that can make all the difference between a successful project and a less successful one. While MVP is a framework document, it is very important to understand that the client must carefully evaluate their needs while the service provider come up with a solution based on the past performance of the building and the expectations of the client. The role of the protocol is to educate the parties of the pitfalls and the opportunities ahead before going ahead with the project.

Cost-effective M&V of energy and IEQ parameters

It is a well-known fact that project cost is directly linked to the number of measurement points. Equipment needs to be calibrated, installed, periodically checked and re-calibrated to maintain the accuracy of the data that is being

collected. In between these procedures, a team of experts must collect and analyse data to verify the savings and make sure that the indoor environmental conditions are being met.
Each project is an opportunity to gather more data and improve the process by refining the model that leads to cost-effectiveness of energy efficiency projects. Companies that have refined the techniques to measure and verify energy savings based on their past experiences can employ similar methods to cost-effectively measure the IEQ parameters as well. For the benefit of everyone, here are some excerpted passages from the MVP (MVP 2000) that list the factors influencing the cost of determining energy savings. They are:

- MVP Option selected;
- ECM number, complexity and amount of interaction amongst them;
- Level of detail and effort associated with establishing baseyear conditions needed for the Option selected;
- Amount and complexity of the measurement equipment (design, installation, maintenance, calibration, reading, removal);
- Duration of metering and reporting activities;
- Accuracy requirements;
- Experience and professional qualifications of the people conducting the savings determination.

Often these costs can be shared with other objectives such as real time control or operational feedback to improve the indoor environmental conditions inside a building. Under normal circumstances, it should be an objective of M&V planning to design the process to incur no costs above those needed to provide adequate certainty and verifiability in the reported savings, consistent with the overall budget for the ECMs. As a rule of thumb, the average annual M&V cost for determining energy savings should not exceed 10% of the average annual savings being assessed.

In addition to the monitoring requirement to verify energy savings calculations, the second volume of the MVP (MVP 2000) also lists the IEQ measurement and verification procedures that may be used to address the following goals:

1. Ensure that the energy conservation measures have no adverse influence on IEQ,
2. Quantify the improvements in IEQ resulting from implementation of energy conservation measures, and
3. Verify that selected IEQ parameters satisfy the applicable IEQ guidelines or standards.

It is important to realise that uncertainty in energy savings calculations and cost of doing M&V should be balanced. The acceptable level of uncertainty required in savings calculation is a function of the level of savings and the cost-effectiveness of decreasing uncertainty. For example, suppose a project has expected savings of $100,000 per year and that a basic M&V approach had an accuracy no better than ±25% with 90% confidence, or $25,000 per year. To improve the accuracy to within $10,000, it would be reasonable to spend an extra $5,000 per year on M&V but not $30,000 per year. The quantity of savings at stake therefore places limits on the target expenditure for M&V. This example works well with energy savings which can easily be converted into a dollar number but as discussed earlier, it is much more difficult to associate dollar numbers with improved indoor environmental conditions.

It should be noted that the author is cognisant of the fact that the value of this paper would be greater if one or two actual case studies could have been included as examples. While this may happen in future, most of the ESPC projects are covered by confidentiality clauses that forbid the use of data from the projects. These are considered proprietary information by the ESCOs who are not willing to share it as they feel that their competitive advantage may be at risk.

4. CONCLUSIONS

While retrofit projects offer a very good opportunity to improve indoor environmental quality of buildings, the actual implementation of those projects is quite cumbersome and offers many practical difficulties. Firstly, the contracts need to have proper checks and balances for projects to materialise; Secondly, the concepts and best practices for improving indoor environmental quality must be properly understood by facility managers; Thirdly, the management may need to work with and educate the employees to derive the maximum benefits from the implemented measures.

While the debate related to tangible and intangible benefits will likely continue for some time until more definitive research in the field of indoor health and productivity can answer some key questions, there is no denying the fact that in the future, building performance will be progressively judged against a higher standard. And, any metric that will be used to evaluate building performance will have to take into account both energy efficiency and indoor environmental quality of buildings.

5. REFERENCES

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6. END NOTES

[1] MVP is the new and easy to remember term that will replace IPMVP in due course of time.

[2] Practice of paying for services that are an end in themselves such as satisfying the cooling needs of occupants (24 °C and 50% RH in all spaces) as opposed to paying for electricity that can then be used to provide the required cooling.

[3] For more information, visit the web site at http://products.bre.co.uk/breeam/default.html

[4] The US dollar (USD) to EURO conversion is approximate only in this paper.

[5]To save energy, economiser systems automatically increase the rate of outside air supply above the minimum setpoint during mild weather.

[6] The term supply air dumping refers to the tendency for the jet of cool supply air exiting a supply register located at ceiling level to drop toward the floor without sufficient mixing between the jet and the warm air within the room. Supply air dumping, which is more common with low supply flow rates, lower supply temperatures, and certain supply diffuser designs, is a source of thermal discomfort.

[7] Personal experience while reviewing the M&V plans under Federal Energy Management Program's (FEMP) SuperESPC projects and from personal conversations with FEMP project facilitators.