Energy Efficiency: The Role of Theory in the Real World

By **Bill Holmes, P.E.** August 26, 2011 12:44:34 pm

I recently read one of the most amazing books of my life; Tracy Kidder's Mountains Beyond Mountains. The cover describes the book as "The Quest of Dr. Paul Farmer, a Man Who Would Cure the World." The story is about Dr. Paul Farmer, a Harvard professor of both medicine and medical anthropology, a man with an MD and a PhD who spent eight months every year, without pay, treating patients in small villages in Haiti under the most difficult living and working circumstances imaginable. As a result of his field experience, this brilliant Harvard professor made discoveries that may have almost single-handedly stopped a world-wide pandemic of drug-resistant tuberculosis.

A couple of quotes from the book just jumped out at me. Kidder writes, "Farmer told me that he found his life's work not in books or in theories but mainly through experiencing Haiti: 'I would read stuff from scholarly texts and know they were wrong.'"

Kidder also wrote, "The circumstance of Haiti suited Farmer temperamentally because, for all his scholarship and interest in theories, his strongest impulses were pragmatic. He only seemed like a nerd. He would tell me years later, with undeniable accuracy, 'I'm an action kind of guy.'"

While I am a nerd but certainly not a brilliant physician saving the world, Dr. Farmer's story contains strong lessons that relate to my life and I think all energy professionals could learn from him about the roles of both the theoretical and the pragmatic.

In 1974, in the middle of the first "Oil Crisis," I was hired by an engineering consulting firm to start an energy conservation department. For five years I did energy audits, studies, projections and designs, all headed toward capital projects. The assumption was, and for the most part still is, that the way to save energy is to buy something. Of course, it is no coincidence that most companies in the field make their money by selling something.

But after a few years in the consulting firm something began to bother me. The projects we did were to save energy, but no energy was saved during the audits, the detailed studies, or the preparation of reports. No energy was saved during designs, the writing of specifications, or construction. The energy was only saved after the engineering was done, the systems were started up and we turned them over to the operators, the technicians and the maintenance people.

The engineers were finished. In most cases, they never saw what happened unless there was a problem. The owners weren't willing to continue to pay the engineers after the engineering was done. I once heard an architect say, "I designed a $14 million dollar building and then saw it turned over to someone making $7.50 an hour to operate and maintain." Something just didn't seem right about that. I wanted to know what happened after the engineering was done. I wanted more. I wanted to be where the action was; where the energy was actually being used.

So in 1979 I started my own business and began contracting to serve as building energy manager for a number of facilities. I had no idea what I would find or how much I could save. To pay the bills, I took a position as assistant professor in the Purdue School of Engineering and Technology, which I kept for six years until my business grew to the point where I could no longer do both.

During that period of my life I worked 80 hour weeks on a regular basis. In the afternoons and evenings I was teaching thermodynamics, fluids, thermal systems, power systems, HVAC design and energy

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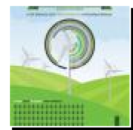

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Author Bio

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Bill Holmes, P.E. founded Holmes Energy LLC www.holmesenergy.com and developed the AutoPilot Monitoring-Based Commissioning (MBCx) System in 1979. He has a B.S. and M.S. in mechanical engineering and has done additional coursework and research for his PhD. He is a former Purdue professor and taught for several years in the Continuing Education in Energy Management Program at the University of Wisconsin.

Bill has produced savings from 20% to, in a few projects, more than 50% from low-cost, no-cost changes in management, operation, maintenance and control alone in all types of facilities including Industrial Plants owned by Fortune 500 Companies.

He is the recipient of a DOE Award for Energy Innovation and was the Indiana Energy

conservation classes. In the mornings, sometimes at 5 AM and many nights after my last class ended at 10:30, I was out in buildings; operating and controlling them, maintaining comfort and managing all maintenance for energy systems.

How well did the theory prepare me for the real world?

As I describe in my upcoming book, Would You Fly in This Building?, in theory, receiving part of the savings seemed to be a good arrangement because I was certain there must surely be savings opportunities somewhere in there. But I had just come out of my first customer's main mechanical equipment room, where the heating, cooling, water heating, and ventilation equipment was running, and I was hit with the realization that not only did I not have a clue as to how to save any energy, I knew very little about how that equipment operated and how energy was actually used in the building.

I was a Registered Professional Engineer. I had a Bachelor's and Master's in mechanical engineering. I had been out of school 12 years and had started and run an Energy Conservation Department for five years. What was I worried about?

Engineers are generally pretty smart people. But since the early '60s after the beginning of the space age, engineering curriculums became filled with so much theoretical science and math that there wasn't room to include all of the old traditional subjects such as foundry, welding, machine shop, drafting, etc. Those became the venues of the contractors, the servicemen, the technicians. If engineers could design those complicated energy systems, the hands-on guys could make them work.

They didn't teach me about the actual equipment, the pumps and boilers and chillers and cooling towers, in engineering school. Boiler rooms are scary. Ever been in one? They're hot, they're noisy, they're dirty. There is oil dripping and puddles on the floor. They smell bad. And there's this hissing sound coming from the boilers. You're just sure that when you get within about three feet of a boiler it's going to be Hiroshima all over again. I used to have nightmares about places like that when I was a kid. But they are the places where most of the energy is consumed.

I knew how to design a boiler, a chiller, a pumping system and I could stop by a nice quiet clean mechanical room to compare what the contractor was installing with what was shown on the drawings, nod my head and say, "that looks good" or "move that pipe back against the wall." I could even watch as the system was started up and tap on a pressure gage to make sure it was reading properly. After all, I was a graduate mechanical engineer.

I was baffled and I was on my own. I didn't know a single engineer who could answer my questions about the equipment and controls. The only approach I could think of to help me figure it all out was to fall back on the most basic engineering fundamentals; what I learned the first semester of my freshman year. From my thermodynamics background I saw every building as an energy balance. Energy came in through the utility meters. Where did it go? Trace it using a top-down approach, from the largest systems to the smallest. I had students in my classes who were running a nuclear plant. They had to account for every Btu and every gram of fuel every day. That's where my idea for a monitoring system came from; if they could account for all of the energy in a nuclear plant, I should be able to do it in any building. And I found that to be very effective. I eventually could account for where and when every energy dollar was spent within a facility.

So I designed and installed a system to monitor all of the significant energy consuming systems to determine where all of the energy was actually going. Then I compared that data with the theory, my "energy model." The difference between the two was the opportunity for savings, which in that first project turned out to be 59% actual documented savings. But those savings didn't result from a one-time purchase of more equipment; they resulted from continuous monitoring and management, an ongoing process. (I later had a project in an ice arena where a substantial investment had been made in energy improvements just a few years earlier and all of the savings had been lost through poor operation and maintenance by the time I took it over. The arena was using more energy than it had before the improvements.)

The monitoring system also included sensors to ensure that quality and comfort were maintained. As changes were made to save energy, I needed to be able to track building conditions, energy efficiency: KW/ton, CFM/KW, Btu/Widget, therms per BIN or Degree Day. One of the biggest opportunities for me has always been oversized equipment with poor part-load efficiency. I understood the engineering behind each energy process, so I built the analysis into the software.

Although I often hear people say part of the role of an energy manager is to assure that the systems are operated the way the designer intended, that would be a serious mistake. You cannot assume that the systems were designed for maximum energy efficiency, or if they were, know that the design had not been seriously compromised trying to stay within the construction budget. You cannot assume that they were installed properly either. Over the years I have found wrong systems, wrong designs, wrong sizes, wrong controls, etc. The systems really need to be operated every hour of every day for maximum efficiency, quality and comfort, an ongoing process, not a one time theoretical exercise.

When I was working for a consulting firm, I had little opportunity to be involved with building systems on an in-depth basis; that was turned over to contractors and maintenance people. When I was actually

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running buildings, I had almost no interaction with the designers who had finished their job. I was fortunate enough to run buildings in Columbus, Indiana designed by I.M Pei, Richard Meyer, Kevin Roche, Cesar Pelli, Ero and Eli Saarinen, Harry Weese and many other renown architects. I saw what worked well and what didn't in buildings designed by the greatest architects in the world and was able to create and maintain energy savings averaging 35% in all of those buildings.

What some people in the real world think about theory

Also in the book is part of a conversation I had with Randy, the head of maintenance for a large school district. Randy wasn't a bad guy and he managed to keep most of the equipment running most of the time, but he seriously overestimated his knowledge of engineering. We had been talking about how I found opportunities for savings using our monitoring system when I mistakenly used the term, "theory."

"That theory don't work out here in the real world," Randy said. "You know, it's just a theory. It might be right and it might be wrong. It's just a theory." I tried to explain that in this case, theory meant physics – it's always right. I explained that we monitored how the systems were actually working and how much energy they were actually using and compared that with how much they should be using according to theory, the Energy Model. The difference was the opportunity for savings.

People may not understand the physics and may misapply it, but it is always right. Randy did make me think, though. How many others had the same idea when they heard an engineer talk about the theory? I never forgot that.

The role of energy modeling

A hot area of interest these days, along with energy auditing, is energy modeling. Just last week I got a call from a recruiter wanting to know if I could recommend anyone to do energy modeling for a growing company. I hope that people realize that an energy model is just a tool and it doesn't necessarily reflect the actual energy use of a real building occupied, operated and maintained by real people. It's kind of the like the EPA mileage rating stickers with the disclaimer "actual mileage may vary."

Within the last month I was asked by a very large company for my view on energy models. My response was, "I have used modeling for years but other than as a part of a design it is only useful when used in conjunction with actual monitored data on an ongoing basis. You must have actual data, you must have software that compares the two on a continuing basis, and you must have people who can understand it all. The difference between the model and the actual is the waste and the opportunity for savings. I think the industry is overusing modeling with the idea that it represents the real world. You can model the systems but you can't model the people who operate and maintain them."

How to fit theory and the real world together

What was obvious from my first project was that while I was teaching the theory in the classroom, how the energy systems should be designed and operated, I was seeing something completely different in the field, the buildings, the real world. There was often little similarity. To paraphrase Randy, "That theory just weren't working too well in the real world."

There is often a big gap between those in the field and the engineers who think that once the calculations and design are done, the problem is essentially solved. Some engineers think they know it all and may overestimate their knowledge of the field as much as Randy did his of the engineering. They often don't understand the real world where Randy and others live. Some think it is beneath them.

Frequently, those in the real world are stuck with a system or equipment that looks really good in theory, but doesn't work. They have to fix it, to make it work. I have spent a lot of hours both designing systems and trying to make those designed by others work to satisfy the actual building needs. I had friends in the facilities department at Purdue, who were graduate engineers, tell me that it often took them two to three years to get a new building operating in the manner required to serve its function and occupants.

I think what jumps out at me as the two central issues that I have been dealing with for more than 35 years, are the gap between the theory, those in academia and design offices and those in the real world working with the energy systems on a daily basis, and second, the lack of monitored data and feedback to verify the system operation on a continuing basis. I really believe my perspective is different than most due to my combination of theory and extensive hands-on experience. My views are based on what I have encountered in the field compared with what was supposed to happen. I was on call 24/7 for many years. I have walked on both sides of the fence and believe me, the skill sets required are very different.

Those on the theory side need to understand that their models and calculations don't necessarily reflect what actually happens in the real world. They need to demand actual, continuous, monitored data for the systems that are actually using the energy every hour of every day. And that data needs to be continuously compared with the theory, the models, both to ensure that the systems are being operated as designed as well as to verify that the designs were correct. There needs to be a continuous quality control process. This is not a new concept, but it hasn't been widely applied. Howard McKew, P.E., wrote in an article in Heating/Piping/Air Conditioning nearly 20 years ago, in October 1992, "A comprehensive quality process always requires data collection after the energy measure is in place. Engineers often leave this step unfinished."

On the real-world side, the keys are incentive, training and tools. I have encountered almost no one in the field actually operating and maintaining the energy-consuming equipment who has the required training and skills. Most are trained to do their job, to run or fix a specific piece of equipment or system just to keep it running. And they are not normally the ones paying the utility bills or responsible for the costs.

Many are disdainful of the theory and the "college boys" as Randy was. They must be given an incentive from top management, training to understand and view the facility's energy consumption globally, as well as the individual systems, and the information required to track and manage it. No matter how good an employee may be and much they want to succeed, without the three essential keys they will never be able to realize the full potential that exists in all facilities.

Lastly, it takes people from both the "Theory" and the "Real World" working together to achieve success. That is why airplanes have instruments, highly trained pilots and maintenance organizations in addition to designers and builders. The building industry needs to follow suit.

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