Energy Master Planning for Mechanical Systems

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Summary

Property is a principal asset of most corporations. Not only is property inherently of large value, it is also where most income is generated and operating costs are expended.

A reduction in building operating and energy costs can save up to 8% of the total corporate costs. An improvement in occupant comfort and productivity can increase corporate income by up to 25%. These improvements can add up to an increase in profits of as much as 70%. The outlay to achieve this is the cost of planning and better design, no increase in installation costs.

Mechanical systems are responsible for 70% of occupant complaints, 70% of the total energy systems life cycle operating, maintenance and energy costs, and 70% of the deferred maintenance in buildings. Changing mechanical system characteristics to sustainable, high performance should be a priority.

70% of US buildings currently suffer from deferred maintenance. This causes a doubling in building operating costs, increased energy use, and a reduction in occupant productivity, which further causes reduction in the worth of the buildings.

Turning theses losses into gains and profits requires taking full control of existing and future buildings and, in particular, their energy systems. An Energy Master Plan (EMP) is a long-term plan for a building or facility's energy systems that steadily moves them toward a sustainable, high performance future.

Introduction

40 years ago, mechanical systems were reliable, able to provide good comfort conditions, and preventive maintenance was the norm. Ironically, the 1970's oil crises not only moved oil to a more expensive and less reliable commodity, they caused mechanical systems to move that way too, against the logical trend of improvement.

In fact, since 1973, the development of building science and computer simulation, new light sources, glazing systems and electronics have removed all the stumbling blocks that prevented buildings from being highly efficient and high performance buildings. Owners have not taken advantage of these developments and buildings remain major consumers of energy, supplying quite poor comfort conditions and with deferred maintenance in epidemic proportions.

A building owner who is looking at short, medium and long-term business decisions up to 10 years should consider the consequences of not enacting an energy master plan and become fully cognizant of the probable consequences.

A sustainability plan is really a success plan and is essential for any business that intends to be successful long-term. Hospitals and Schools have more reasons to plan for sustainability because they own the buildings from design through to deconstruction; they pay for the operation and maintenance; they require the best comfort conditions to provide the best learning/healing environment, and they all have rapidly rising, uncontrolled operating expenses.

What Owners Want From Building Mechanical Systems

What do owners really want from their building mechanical systems?

Great comfort with no complaints from occupants and no sick days or absenteeism caused by the building environment. Very low, or no energy costs with no peak monthly costs in either the heating or cooling season and total reliability and security of energy supply. Low and reliable operating and maintenance cost. The system must be easy to remodel, modify and alter to building churn and resale. The systems should be efficient and effective for a long life cycle. The least installation cost is required but at the same time it is understood that this is a very small portion, only 2% of the total 30 year costs, so if other attributes can be improved for a quick payback, it can be worth investing in extra installation costs.

In short, owners want a long life, loose fit, high performing system for the least installation cost. There is very little variation in the requirements from owners, some require less adaptability and expandability, some would like greater efficiency, and the very wisest would like to maintain optimum comfort for the highest productivity from the occupants. The main difference between the above and a sustainable, high performance system is a sustainable system will have a plan to move to net zero energy in the future. With the inevitability of large increases in energy costs and the reliability of supply becoming more and more unpredictable, planning the move to net zero energy is becoming a more palatable proposition for owners.

What an Energy Master Plan Develops

Put simply, an Energy Master Plan or EMP, is a detailed, long-term success plan for a building or a facility's energy systems. An EMP looks at the detailed short, medium and long-term sustainable, high performance goals and objectives for building energy systems and provides a comprehensive plan to attain them.

Every EMP must examine three main performance criteria for every piece of the plan: Energy, Maintenance, and Productivity. The first step is to set end goals in these areas. Typical end goals are:

Reduce Energy Use to Net Zero (carbon neutral)
Reduce Maintenance by 75%
Improve Productivity by 25%.

These are sustainable, high performance end goals. No timeframe should be set; this is up to the Owner and will depend on the return on investment strategy the Owner places on implementation criteria and improvement investments.

From here, EMP's need a framework for planning and achieving these goals. The Natural Step (TNS) is one such framework that uses an important tool, backcasting, that keeps the focus on the end goals while developing the existing systems in steps that move steadily and unerringly toward the end goals. Another way to look at backcasting is that it prevents the designs from drifting down blind alleys. Backcasting works back from the end goals and looks at every project with the end goals in mind. Decisions made with end goals in view may be very different from decisions that would be made with a short-term view only.

Example: If a major office building extension in the Philadelphia area requires replacing the 50year old boiler plant, 4 to 6 large hot water, gas-fired condensing type boilers would be a good choice for current high performance. However, with sustainable end goals and steps toward them already planned, the choice may be for a solar heating panel array with storage combined with a small, modular gas-fired condensing boiler plant only 30% of the original plant capacity. This choice is a better selection for the end goals because it will significantly reduce energy use, be a step toward the eventual goal of no boilers, and be flexible and adaptable for additional solar. It will also provide a segue way to using solar heat in the cooling months for dehumidification, a further step in the sustainability plan, and so begin the further morphing of the mechanical system into a sustainable, high performance system. The choice is moved from a conventional boiler plant to a much smaller modular plant with a significant solar array.

An example of a blind alley: Installing ground source heat pumps in a new or existing building with fan-assisted variable air volume HVAC systems, a currently popular "green solution". The ground source may be good for future development, but the variable air volume system is a blind alley that will not only perform badly now but will require total replacement to develop into a sustainable, high performance system. All-air systems should never be considered to be either sustainable or high performance.

The Answer to the High Cost of Building Operation

The primary dictionary definition of sustainable is: able to be maintained. Architects and engineers gloss over this definition and refer to the secondary definition: avoiding lasting environmental impact, etc. Without a comprehensive preventive maintenance program, all other performance qualities are degraded, if not lost, and taking "able to be maintained" to it's deepest and broadest meaning will cover the secondary meaning.

In 2006, the American Institute of Architects (AIA) adopted Challenge 2030, where, by 2010 buildings should have reduced their carbon emissions by 50%, and, by 2030, carbon emissions should be down to net zero, or carbon neutral. The US Council of Mayors has signed on to this challenge.

We assisted writing the ANSI Climate Neutral Building Standard, published December 2006, that has the objective to move 60% of the current US building stock to climate neutral within 5 to 10 years. This standard is the first to require detailed life cycle performance analysis and documentation and includes the required methods and strategies to obtain the needed goals and objectives.

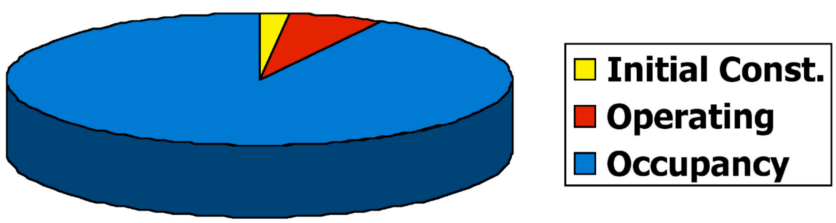
Strategies for Sustainable, High Performance Mechanical Systems

"Failing to plan is planning to fail" should be the mantra of sustainable design. Owners and their planning and construction team need to plan every move in detail, from conceptual design to deconstruction of the building.

Mechanical systems play a significant role in the total building energy use. Planning for a sustainable, high performance system takes significant application of expert knowledge in the design, construction and life cycle operation of the systems. Experts, applying building science and providing detailed documentation of the predicted life cycle performance, is the only way to assure long-term success.

Selecting the design team determines the success of the building performance. Charts and graphs of where the greatest influence occurs in building design generally do not include design team selection, but it's the most critical selection in the whole process.

The owner must select a design team with expertise in life cycle performance evaluation. The owner must seek out expertise in use of the best planning and building performance evaluation tools such as TNS, ESPr and EnergyPlus. Unfortunately, no tools provide reliable long-term performance evaluation information of mechanical systems, currently that must come from individual expertise.



30Year Building Costs:
2% Initial Construction, 8% Energy & Operating, 90% Occupancy

Only 2% of the total 30year operating costs are for initial design and construction. Yet 98% of the design and construction effort is placed on the initial 2% construction and start-up only. Long-term building performance should be a much bigger priority.

Current mechanical system 30year operating costs could be eliminated. High performance mechanical systems can increase occupant productivity by over 8%. Each of these improvements is worth over 4 times the total construction cost within 30years. These performance facts need to be fully evaluated by the design team.

Integration in Planning and Design/Build/Operation

Whole building/facility integrated planning and design is essential for optimizing all the systems. Buildings and building systems work holistically, one good thing produces a knock-on effect for other good things to happen, and vice versa.

Whole building energy systems dynamic integration is the best method to minimize costs and maximize income for buildings and facilities.

Codes, Guidelines and Standards

Truisms: Designing to code is one step away from jail.
CATNAP: Cheapest Available Technology, Narrowly Avoiding Prosecution.
This doesn't mean designing to code or guideline is inexpensive, only poor in performance.

Good design is not affected by any code. Codes and guidelines are for lowly expectations, not sustainable, high performance buildings. Codes and guidelines are for the lowest quality acceptable, not the highest attainable. A gold level LEED rated building should be considered mediocre performance, not a high performance design. A recent design of ours was assessed for LEED, it scored 3 points above platinum with a probable 4 more points.

The excuse that it costs more money to build a high performing building is totally fallacious. It takes a great deal more planning and design know-how to produce a high performing building, not extra construction costs.

Sustainable, high performing buildings should not be compared to beating any energy or comfort codes as they are in a different league. A zero energy building beats all energy codes by ∞, and current ASHRAE comfort requirements are for creating a 20% to 50% occupant discomfort, a bar so low it should be stepped over easily.

Documentation

Simply put, if there is not a detailed, clear, simple and transparent explanation of how and why the systems and equipment were selected and sized to fulfill the Owner's long-term performance requirements, then it is highly unlikely that the systems will provide the performance required. This is what a Detailed Design Intent document provides, and it's missing on almost every project.

Detailed documentation is an essential for QA/QC and to remove the risk of using different systems and sizing strategies. Detailed documentation of life cycle performance evaluation is essential for every system and piece of equipment to assure success. Implementation decisions should be evaluated and arranged in a performance/return-on-investment matrix as part of the EMP.

A Sustainable Building/Facility Logbook is an essential document that needs to be developed in conjunction with the EMP and DDI. The logbook authenticates and records the sustainable, high performance throughout the whole life cycle of the project.

Energy Performance

Sustainable describes a system that should be zero carbon emissions. There remain options of zero carbon to aim for, zero operating or zero operating plus embodied energy.

Zero operating carbon includes operating energy and perhaps maintenance energy. This goal is not very difficult to attain for most buildings with careful planning.

Total operating and embodied carbon includes all material and equipment energy consumed and used to design, construct, operate and maintain the complete working facility. This is a more difficult state to attain, but very attainable for new buildings. Residences should ideally aim for above total embedded because the occupants also use services such as hospitals, etc., and for a region to be neutral, adding up all the various buildings and types must be zero.

A paradigm shift in mechanical system energy use is needed to move to net zero energy. A reduction of 90% from current systems electrical use is required to enable the switch to renewable sources and zero energy. A planned movement to low grade warming and cooling is needed so that only renewable energy systems need eventually be used. Refrigeration should be eliminated or minimized and moved to heat generated cooling. Any gas or oil-fired boilers should be planned for replacement by solar thermal, ground source, etc. This is not as difficult as it may seem when several strategies begin to work together toward reducing energy use and changing the type of energy required.

Mechanical distribution systems are the key to sustainable, high performance systems. Piping and ducting systems are the infrastructure of the mechanical systems and require the most careful planning, selection and sizing to provide efficient and effective, adaptable, long-lasting systems. Key life cycle strategies must be very carefully examined for energy, maintenance and productivity. Fundamental characteristics of piping and ducting systems must be considered. Pipes require only 12% of the space that ducts require to carry the same thermal energy and piping systems move thermal energy 8 times more efficiently than ducting systems. Selecting an all-air distribution system will require several devious strategies to enable it to be a sustainable, high performance system. A piping system should be used for a substantial portion of the thermal load.

Maintenance Performance

The primary definition of sustainable is: able to be maintained. If a system can't be maintained for whatever reason, i.e., too complex, too many moving parts, too difficult to access, then the system won't be maintained. It's as simple as that.

Every performance attribute relies on the systems and equipment being fully maintained. A deferred maintenance program is caused by deficiencies in design. Systems must be simple enough to be easily maintained. They must be accessible to allow regularly scheduled preventive maintenance. In other words, preventive maintenance is essential.

Productivity Performance

Productivity is the reason mechanical systems are in buildings. When occupants are more comfortable in their environment, they perform better. Better performance by the occupants will produce higher profits. That is the reason why producing the optimum indoor environment must be the primary goal of every mechanical system.

Humans are 50% more sensitive to radiant temperature than they are to ambient (air) temperature, the temperature most guidelines are solely based. To produce the ideal indoor thermal environment, designers must develop a radiant temperature control strategy.

Designers must also develop a humidity control strategy. This is especially true in the US East of the Mississippi, which suffers high humidity in the summer and low humidity in the winter. Humidity control not only provides better comfort but also helps promotes wellness and prevents mold problems within buildings.

Ventilation must be closely controlled. Today's buildings are blowing more air around than earlier buildings, which should raise a huge question mark among designers. Ideally, most buildings should distribute the minimum air volumes around the building, sufficient for ventilation and other necessary controls. Ideally the air should be 100% outside air to eliminate recirculation.

The Way Forward

It seems only common sense that Owners should be provided with a Detailed Design Intent document that provides a transparency and clarity of the design so that they can understand exactly how and why the systems and equipment were selected and sized for life cycle performance. This one document would totally improve the building life cycle performance.

It also seems only common sense that Owners deploy a QA/QC program to ensure the systems are optimally selected and sized for life cycle performance. This involves employing an independent, expert, life cycle performance consultant to partner with the design team and provide a double-check to ensure the systems have been optimally selected and sized and to produce the documentation that proves it.

Owners need to demand sustainable, high performance, and then they will get it. While this may sound simple, it is the largest stumbling block to sustainable, high performance buildings. Owners need to be aware that improving the current popular mechanical system life cycle performance by over 40% can be accomplished by very simple and much smaller systems. Improving these systems is the way forward to sustainability.

Most architects and engineers are paid fees proportionate to the construction cost. There are no incentives or penalties for initial building performance, let alone life cycle performance. Rather, we reward designers for what they spend, NOT what they save. Annual annuities to reward designers and constructors may be a way for owners to provide life cycle performance incentives.

Conclusion

More and more, global climate change, the depletion of the oil supply, and the lack of security in the oil supplies are becoming major topics of discussion by governments, the media and the public. Discussions are being made for net zero energy use in buildings. This is good.

Equally important is the increasing global competition for every service. Soon University and hospital services will be very competitive globally. The sooner a facility begins a sustainability plan, the better position that facility will be in the future. A sustainability plan is really a success plan for the future.

Only by planning for sustainability will it happen: failing to plan is planning to fail. Energy Master Plans should be the foundation on which to build sustainable, high performing building energy systems. An EMP must be part of every response to the challenges facing the marketplace today.

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