Final Version for Publication

A Methodology for Developing Sustainable, High Performance Building Envelopes

Introduction

"Skate to where the puck is going to be, not where it is"
Wayne Gretzky

Firstly, I assert that using this methodology to transition a building, facility or community toward truly sustainable, high performance building envelopes, offers financial stability and huge financial rewards that cannot be matched by other methods.

Current building envelope systems and building mechanical systems rely on tweaking 100 year old concepts to make them high performance. Current design data and methods used by architects and engineers assume the weather conditions will not change for the duration of the building life cycle. Both of these premises are leading us down an unsustainable and poor performance path.

In order to build sustainable, high performance structures, we need to turn 180º in our planning and design development methods and apply building physics, architectural science and engineering principles to begin the process of moving toward truly sustainable, high performance buildings that will have a long and successful sustainable, high performance life cycle. This needs a science-based sustainability platform such as The Natural Step (TNS). We shall also be required to use detailed high performance requirements for occupant health, safety, comfort and performance; and predict probable or potential future weather activity for the next 100 to 300 years.

Background

It has been one hundred years since Louis Sullivan started building skyscrapers with steel structures in Chicago, and the introduction of air conditioning to buildings. Before air conditioning, most buildings had some form of heating, either by steam or hot water radiators, natural or fan assisted convectors or sometimes radiant floors or ceilings served by air or water. Radiant floors were popular in Roman times, served by hot air from fires in what we could consider the original boiler rooms.

In our rush to progress to mechanization and automation, we have neglected to use sound building physics, architectural science and engineering principles. The result is we have dysfunctional building envelopes, dysfunctional mechanical, lighting and acoustic systems and, more recently, dysfunctional computer simulation systems based on the other dysfunctions. The energy crises of the 1970's knocked the stuffing out of the rapid progress being made in building physics in the late 1960's and early 1970's and has set back the sustainability movement four decades. The events of 9/11 also helped prevent progress toward a sustainable future.

Grahame Maisey[1], P.E., Building Services Consultants, Wyncote PA

The Way Forward

After taking a look back at why we are where we are, we now need to take that monster leap forward that is so desperately required from building performance.

We have the tools we need to progress:

- There is a science-based global sustainability platform that we can apply to the construction industry so we may plan and develop truly sustainable, high performance buildings, facilities and communities.
- We have a large array of both new and traditional building materials to select from for our buildings so we can use environmentally sensitive, long life, easily maintained, high performance materials for a sustainable performance.
- We have detailed knowledge of human requirements for health, safety, comfort and productivity to allow us to provide the optimum indoor environment for the building occupants so we may maximize productivity as well as providing a safe and healthy environment so we may develop truly high performance buildings for the occupants.

Therefore, the real question is: Why aren't we using and applying these systems, products, data and knowledge?

Unfortunately, change in the construction industry is the exception rather than the watchword. Applying new data and ideas is not part of the industry. Applying building physics, architectural science and engineering principles has not been the basis for building design and development since the oil crises in 1973, 40 years ago. Existing examples of the way buildings are designed and developed lack any long-term planning; built for today, not even for tomorrow, let alone the next 100 to 300 years. Even when building structures are developed for a 300 year life cycle, the only consideration is the structure, not a flexible and adaptable interior environment or future weather expectations. Most changes come from manufacturers promoting their new ideas and products by providing examples to potential users so they have a sample (however misrepresented or over-stated) to relate to.

Applying Science

The industry has been and is still designing new buildings, particularly building envelopes and mechanical systems, with 100 year old science.

By starting with definitions, we will develop radically different protocols, procedures and processes to develop sustainable, high performance buildings and building envelopes.

Sustainable:

1. Able to be maintained. *This is always neglected in the definition used in the construction industry but is actually the very best definition if we simply take it from its narrowest and obvious meaning to its widest and deepest meaning.*

2. Exploiting the natural resources without destroying the ecological balance of a particular area. *This may be taken to mean a building using environmentally sound materials, and a zero GHG building that is able to be energy independent, generating energy from clean, renewable sources.*

High performance:

Superior effectiveness and/or functions. *This means the building is superior in providing service to the occupants in the building. Most buildings are built to provide a place for the occupants to work, rest or play, so the performance of the building may be measured by its ability to coax productivity and satisfaction from the occupants.*

As a platform from which to begin, we suggest a globally accepted, science-based sustainability one known as The Natural Step (TNS). There are many examples of companies, communities and even countries adopting TNS and thriving on the results. This platform has the methodology and the fundamentals for attaining financial stability and rewards. The principle protocol to assure success is back-casting from sustainable, high performance end goals to our current situation or reality.

(We developed an identical procedure to assure success with our Energy Master Plans so we fully endorse TNS. The real problem has been the lack of faithful application of TNS by others to buildings and the construction industry in general.)

Figure 1, below, depicts the shrinking global resources due to over-exploitation and growth of the human population. It also depicts the fact that we have time to stop the trend and perhaps even reverse it.

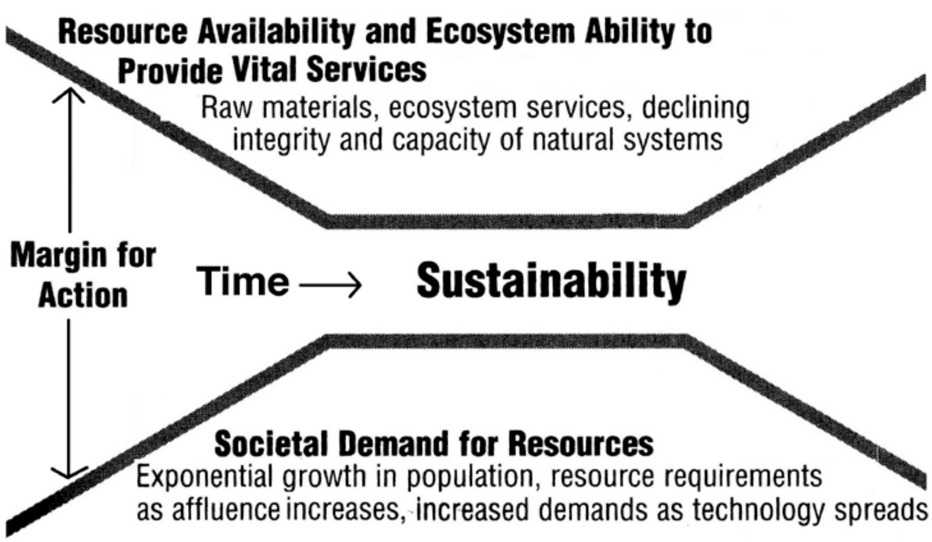

Fig. 1 TNS Sustainability Global Resource Funnel

Figure 2 shows the current trend of development where current practice remains lacking in the true path to sustainability. Again it shows the distinct lack of planning.

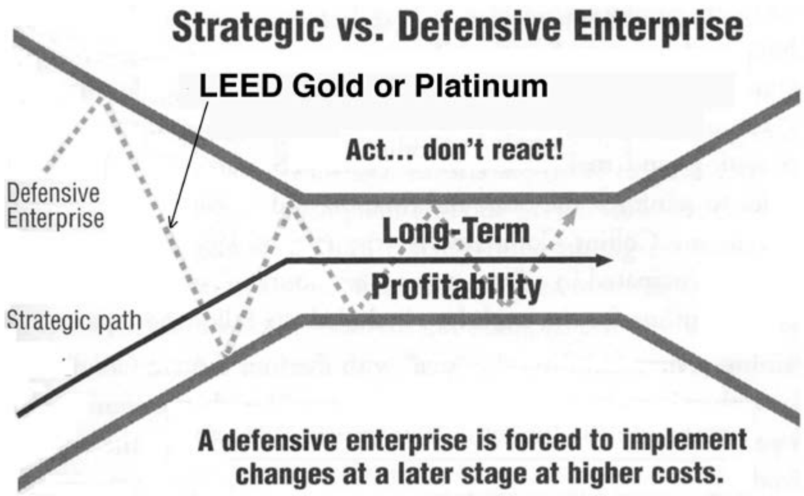

Fig 2. TNS Strategic Path Vs Typical Conservation Path

Back-casting from sustainable end goals, Figure 3, is the main tool used in TNS. It has been consistently proven that forecasting is unreliable. Too often, taking steps to reduce energy or some other performance improvement by a percentage causes poorer performance in other characteristics. What has also been found is that this method results in a short-lived installation with an expensive retrofit, often disguised as an "upgrade", but none-the-less, a life cycle failure. BSC developed this same exact tool of back-casting when we were developing Energy Master Plans and we can wholly subscribe to the fact that this tool is the most essential tool in planning and developing successful truly sustainable, high performance projects. TNS is a Global sustainability platform and the four conditions of TNS apply to global systems. We are the only consultant to faithfully apply the same principles to buildings and their components plus we added High Performance to the end goals for a comprehensive and holistic solution.

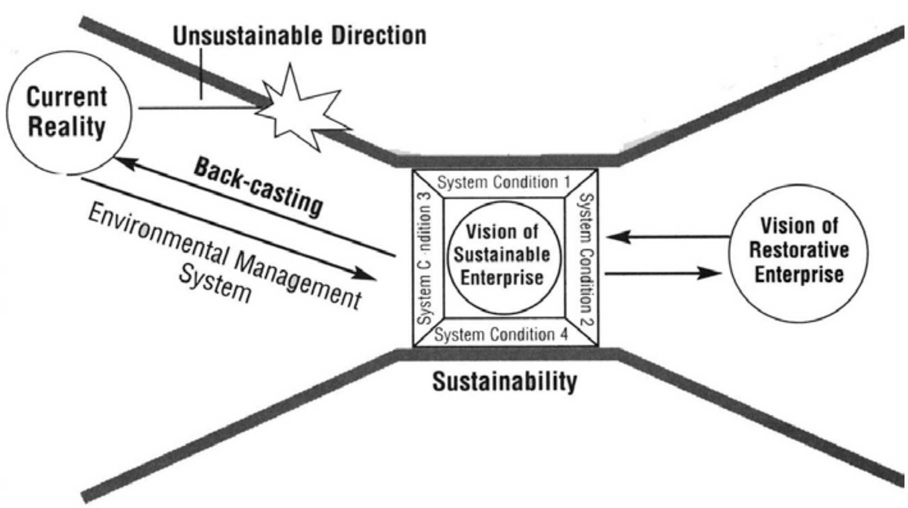

Fig. 3. Back-Casting Protocol For Sustainable End Goals.

Developing the End Goals and Performance Requirements

The TNS platform allows us to develop our end goals and work steadily toward them without being diverted down paths of unsustainable performance.

Now that we have a sound sustainability platform, we need to develop protocols and procedures to apply both the science as well as common sense (the least common of the senses). The primary end goals could be as indicated in Figure 4. A QA/QC protocol is necessary to assure the results. The whole program is developed on a sound financial basis, employing the most prudent strategies to develop the program and total accounting for analyzing payback and life cycle costs and benefits. Every decision is made from a holistic vantage so that all influences are accounted for in every decision.

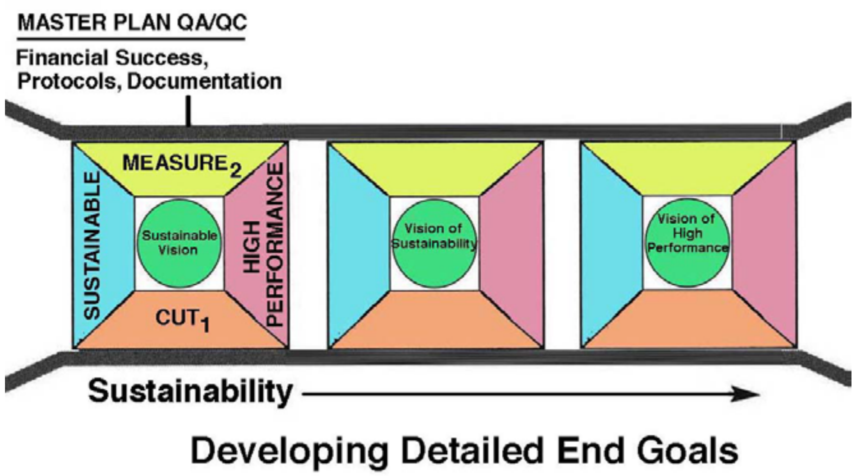

Fig. 4. Sustainable End Goals for Building Envelopes.
First Set: Master Plan with QA/QA

To this end, there needs to be a Total Quality Commissioning process that assures the success of the projects undertaken. This involves providing full documentation, including a Detailed Design Intent (DDI) document which provides details of the design intent in simple language for all to understand, providing total transparency and accountability. MEASURE_2 and CUT_1 are our commissioning acronyms, derived from the original commissioning protocol that helped build the pyramids, measure twice, cut once.

Cut_1 represents Comfort (the most important performance for monetary return), Utility and Thrift, the Owner's most common requests. These stand for Long Life, Loose Fit and Least First and Operating Costs, all while providing the Highest Possible Performance.

MEASURE_2 stands for the list of how to provide the Owners request: Maintainability, Effectiveness, Adaptability, Sizing, Utilities, Remodeling, Expandability and Efficiency. These represent a shopping list to check off.

The Sustainable, High Performance areas require more detailing. We begin with three sets of visions, defining the areas needed within each set and the process or plan of how to attain them. The first task is the overall Sustainable Vision delineated in a Master Plan with QA/QC.

Developing sustainability goals is seeking to obtain a long life, least cost, recycle and low energy solution as shown in Figure 5.

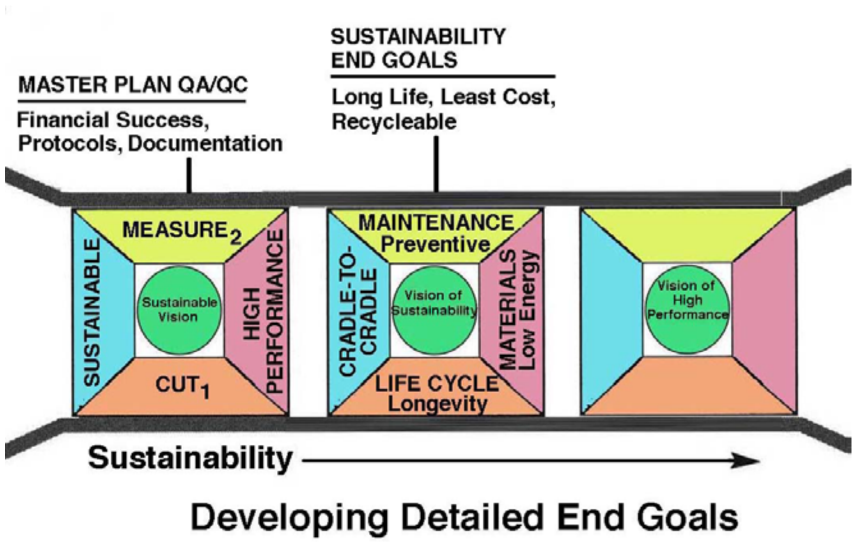

Fig. 5. Sustainable End Goals for Building Envelopes.
Second Set: Sustainability Goals.

This next step covers the Sustainable End Goals for the Building Envelopes. The most important performance goal for sustainability is maintenance. Assuring 100% preventive maintenance is required to secure the continued success of any of the project's other performance requirements. Currently, there are 70-80% of building systems that do not have preventive maintenance, falling instead to deferred maintenance, or worse, a re-construction budget. Optimum health, safety and comfort of the occupants requires that the building operate at full efficiency and effectiveness at all times.

To sustain a successful long life cycle, the building has to be resilient against most expected situations that could arise in the next 150 to 300 years. Sun, wind and rain will be a usual expectancy, but with climate change and climate chaos, we should expect and prepare for extremes in sun, wind and rain, as well as seismic events, particularly in areas affected by "fracking" for natural gas.

From a sustainability standpoint, material selection is the critical characteristic: having the ability to be successively recycled while using minimum energy is the main requirement. Selecting non-toxic, readily available materials is critical for sustainability.

Developing High Performance characteristics will require Resilient, Functional and Adaptable systems as shown in Figure 6. Again, the ability to maintain the systems is all-important and must never be neglected.

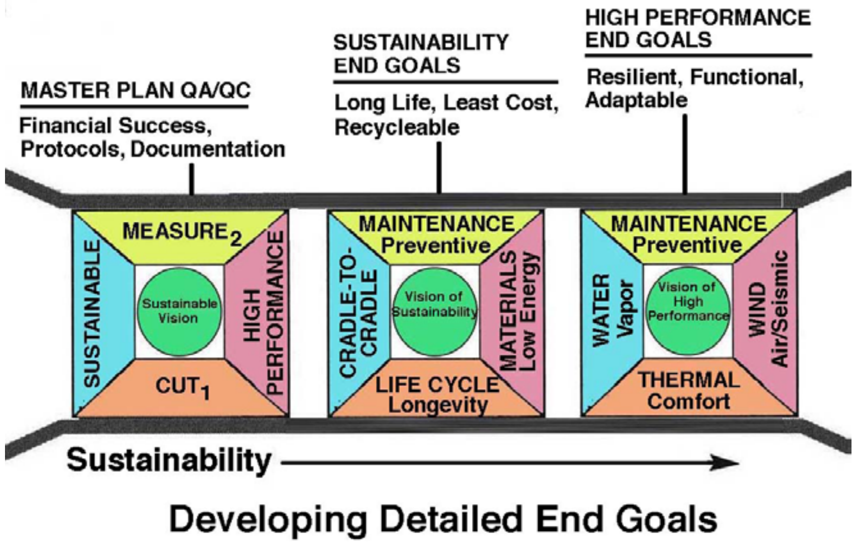

Fig. 6. Sustainable End Goals for Building Envelopes.
Third Set: High Performance Goals.

Most areas in the USA will experience high winds within the next century, so we should allow for 150 mph winds on the building envelope. Most areas will also experience hurricanes with high winds of over 100 mph together with rain at a rate of 5” to 12” per hour. Seismic events will also become more common in many areas, even areas not previously used to experiencing them, especially if the hydraulic fracturing for shale gas reserves continues to expand. Climate change also brings excessive heat and drought for extended periods, as well as excessive cold periods so we should add at least 5°-10°F to both the cooling and heating design data for developing thermal characteristic requirements.

Providing shelter from inclement weather is one thing, but providing a comfortable and satisfying interior experience is what a high performance building envelope can achieve. PassivHaus building is a German high performance standard. However, Germany is a temperate climate that does not experience the hot, humid summers of New York, or the colder, dryer winters. Thus, here in the United States, we require a more stringent standard, one suited to our climate that suffers both hot and cold in the same city.

The Solution

What do all these requirements mean to the planning and designing building envelopes?

We need to develop far more resilient building envelopes if we intend for them to survive for the next 100 - 300 years. All the building envelope components need to be integrated into a low energy, recyclable, whole building concept. These elements include structural, sheathing, insulation and vapor and air barrier systems, as well as the wall and roof penetrations, including windows/glazing and entrance systems.

Building planning and development is similar to planning the life path of people. If we develop really healthy habits and customs, we live a more fulfilling and rewarding life. Buildings seem to take on the same characteristics as a living organism; develop healthy systems and symbiotic components and the building will respond with an excellent performance lasting a very long time.

A major aspect of current building envelope dysfunctional performance in the US is the positioning of the vapor/air barrier. The general rule of thumb is to place the barrier on the warm side. So we separate buildings into either hot climates or cold climates, immediately eliminating 80% of the climate areas in the USA that have both hot summers and cold winters. With climate change, the hot and cold will increase to hotter and colder periods so the situation will only continue to worsen. A common sense solution would be to position the vapor/air barrier toward the middle of the insulation thus protecting buildings in both cold and heat.

We can offset the vertical structural members so we can position a very resilient vapor/air barrier in-between them. The vapor barrier can now be a very resilient board, typically between 1/4” and 1” thick, with a radiant foil or coating on both sides for radiant thermal integrity. Assuming we use 4”x2” vertical structural members, this will give us a wall approximately 9” to 12” deep overall the interior sheetrock and the exterior cladding. The insulation value of such a structure could vary from an R value of 15 to 50 depending on the insulation materials used.

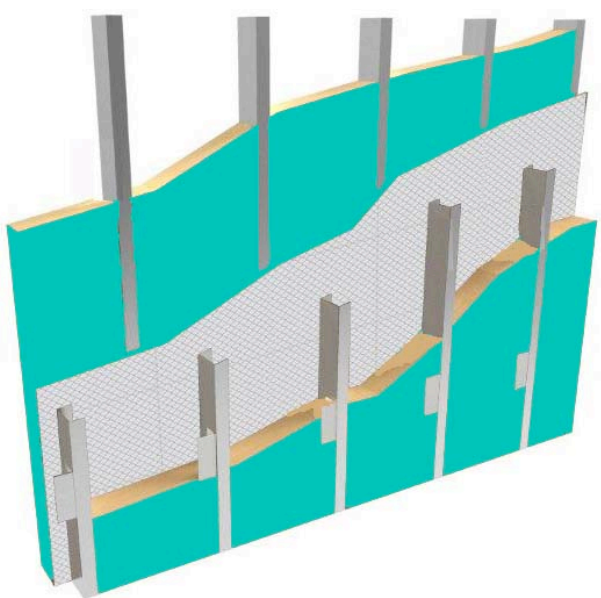

Fig. 7. A Potential Wall and Roof Solution.
Offset structural members, interstitial vapor barrier.

The vertical structural members on each side of the vapor barrier need not be the same size, say the outside members being the major structural item of 6” deep and the inner member 3” deep. This also allows the insulation on either side of the vapor barrier to be different values; in Miami and L.A. we would have 2/3 insulation inside the barrier and in Portland, ME and Alaska we would have 2/3 outside the barrier. The vertical structural members can be made from modern materials that display the life cycle performance we require. Extruded fiberglass with a graphite skin or core would present a low energy system that could be a 300 year solution for buildings up to 10 stories high. This system would also be low energy and the materials plentiful in most areas of the world.

High Performance energy and comfort requirements from mechanical systems would require an R value of approximately 25 to 40 in a wall system and an R value of 40 to 60 in a roof system. The weak links in building envelope thermal performance are the windows and entrance systems. Most high performance window and door systems that have PassivHaus quality performance are double the typical performance of current systems being installed in the US; however, we require even better performance than currently available. As a rough guide, if we desire to have a decent amount of glazing, we need the glazing or window systems to have almost 50% of that of the wall system into which they are going. For example, if we have R25 in a wall, ideally we have an R12 window. There are R20 and up to R40 glazing systems available today, but an R11 operable window is about the best currently offered. The problem is we need frames with no heat bridges.

Entrances/doors offer a very similar problem. A good solution is to require entrance lobbies or halls to minimize infiltration with every door opening.

The high wind, hurricane, tornado and seismic resistant structure requires further examination. The above structure can be made to be very resilient by simply selecting suitable size structural members and materials.

Another wall system particularly applicable to basements, underground areas and other areas subject to insects and pests is to use 5,000 lb concrete surrounding insulation and perhaps fiberglass structural reinforcements. Five thousand pound (5,000 lb) concrete has the ability to repel most destructive pests and provides a water and vapor resistant material, as well as structural stability. Concrete in small amounts may be considered a sustainable solution as the material gradually absorbs carbon throughout a very long life cycle.

Conclusion

Developing a truly sustainable, high performance building envelope using science and a sustainable platform will provide the most thrifty and expedient solution. There will be little modifications required throughout an efficient and effective long life cycle. Future vagaries of weather will be accounted for and therefore handled competently. Future developments in cladding and potential solar applications will be accounted for and thus will be less expensive and able to be applied expeditiously.

NIBS Resilient Buildings Summit, December 2010, Washington DC took the typical current approach of piecemeal development rather than planned development. It is time the US Federal Government took the lead rather than waiting to see what others can achieve first. NIBS could directly apply the method outlined above and simply add a further set of end goals for security for resilient and secure buildings to be developed.There are many inferences in the conference to applying science to buildings but little actual real application of science. Indicating integrated design does not make designs actually integrated because very few architects and engineers actually are capable of developing truly integrated planning and design. A key to the failure is, in fact, indicating integrated design, which, by itself is an oxymoron. Integrated development first requires detailed integrated planning before any design. Most design charrettes are failures because there has been no planning charrette to develop master planning for sustainable, high performance end goals.

The temptation to use incremental targets should be avoided as it has consistently been proven to be costly and fails as a sustainable solution due to the excessive life cycle cost. Buildings should be treated as 100 to 300 year systems rather than the current typical 20 to 50 year cycle. As such, we need to move away from current “Green Codes” with interim targets and hazy and mysterious potential end goals, such as LEED® and Challenge 2030, and embrace a science-based, globally accepted sustainability platform, The Natural Step (TNS), and apply it faithfully to buildings, facilities and communities.