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Improving the Performance of Existing Commercial Buildings:

The Chemistry of Sustainable Retrofits

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Executive Summary

There are approximately 4.8 million existing commercial buildings in the United States. Commercial buildings have an impact and an influence on every man, woman and child in the country. They are our offices, stores, healthcare facilities, schools and places of worship, our warehouses and storage facilities, hotels and places of assembly.

Yet as a group, these buildings are not sustainable—not for the long-term business goals of their owners and operators, and not for the health and welfare of their occupants and visitors. Retrofitting our existing commercial buildings is one of the key steps to overcoming the economic and environmental challenges we face.

Such a shortfall in sustainable performance has considerable impact in three key areas—economy, ecology and society—commonly known as 'the triple bottom line.'

Existing commercial buildings were responsible for more than 20 percent of the nation's total energy consumption (6,680 billion BTUs) in 2008 and 17 percent of annual greenhouse gas (GHG) emissions in America.

Many business benefits for building owners and facility managers can result from improving the sustainability, including reducing energy consumption—and therefore carbon footprint—of existing commercial buildings. Reduced operating and maintenance costs, positive public image and recognition for corporate social responsibility, employee productivity, health and safety leading to higher tenant attraction and retention rates and enhanced resistance to severe weather events top the list.

The sustainability of America's existing commercial building stock depends, however, on the removal of several significant barriers and a holistic approach. Even a minor upgrade to a single structure can often be fraught with hurdles, including conflicting priorities and benefits between owners and occupants, elevated payback periods beyond the expected 3.6 years typical of most commercial building owner, capital constraints for both energy end-users and upstream financers and lack of information or awareness of key energy efficiency measures and how to deploy them.

There are many approaches and tactics that can be employed when it comes to improving building performance. Some are easy, quick and cost little to achieve. Others require more effort and moderate investment. And at the top of the best-practices scale in terms of effort, expertise, investment and results is the comprehensive, whole-building performance retrofit.

It should be noted that performance retrofits and the restoration of the existing building stock are inherently sustainable. Every time we reuse a building instead of tearing it down and building a new one in its place we:

- Keep construction debris out of landfills
- Preserve the existing embodied energy of the building
- Prevent the need to use new construction materials that are energy intensive, including aluminum, glass, steel and concrete

Chemistry will play a pivotal role in improving the sustainability of America's existing commercial buildings. Chemistry is the building block of construction, found in almost every component of every structure. These materials can be used in almost every aspect of a commercial building performance retrofit. From building envelope systems to efficient HVAC system components, hardscaping and emerging renewable energy technologies, chemistry helps enhance energy efficiency, durability and speed of installation while reducing environmental impact and lifecycle cost.

1.0 Economy, ecology and society—the impact of commercial buildings

There are approximately 4.8 million[1] existing commercial buildings in the United States, accounting for approximately 70 billion square-feet of space[2] available for occupation. Commercial buildings have an impact and an influence on every man, woman and child in the country. They are our offices, stores, healthcare facilities, schools and places of worship, our warehouses and storage facilities, hotels and places of assembly.

Yet as a group, these buildings are not sustainable—not for the long-term business goals of their owners and operators, and not for the health and welfare of their occupants and visitors. Retrofitting our existing commercial buildings is one of the key steps to overcoming the economic and environmental challenges we face.

Approximately 40 percent of these buildings were constructed prior to 1970—before the development of modern building and energy codes[3]. They were built before the energy crisis of the 1970s—decades before the formation of the United States Green Building Council and its Leadership in Energy and Environmental Design (LEED®) rating systems. In addition, many of the buildings constructed more recently do not perform as well as their designers intended, nor as well as their owners and occupants expect, whether through the use of shorter lifecycle materials, faulty installation, lack of maintenance or simply years of wear and tear.

This lack of performance has considerable impact in three key areas—economy, ecology and society—commonly known as 'the triple bottom line.'

Economic Impacts and Opportunities

Existing commercial buildings were responsible for more than 20 percent of the nation's total energy consumption (6,680 billion BTUs) in 2008—in a business-as-usual scenario, consumption is forecasted to increase 1.5 percent annually until it reaches 8,010 billion BTUs a year by 2020[4]. At an estimated cost of $3 per square-foot[5], commercial building energy expenditures currently approach the $210 billion mark. Volatility in world energy pricing and supply create havoc with budgets and, often, the threat of real economic hardship.

30 percent of the energy used in buildings is done so inefficiently or unnecessarily[6]. Therefore, the most cost-effective, lowest-risk energy source and stabilization tactic is improved energy efficiency—regardless of whether the price of oil is high or low.

The World Business Council for Sustainable Development (WBCSD) estimates that at US$60 a barrel, simple energy efficiency investments can achieve a 40 percent reduction in consumption with a five-year payback through reduced energy bills, and extending the investment to improvements that offer a five- to 10-year payback can reduce consumption by 52 percent[7].

McKinsey Global Energy and Materials (McKinsey & Company) calculates that, relative to the business-as-usual baseline for 2020, an up-front investment of $125 billion in improving the energy efficiency of commercial buildings over the next 10 years can save $290 billion by 2020 and $37 billion annually thereafter[8].

While the hard dollars in operational savings represented by energy efficiency improvements are largely tangible and easy to forecast, many of these tactics also contribute to related economic benefits that are often harder to identify and measure. For example, upgrades to the building envelope (also referred to as the enclosure or shell) and HVAC system can not only reduce energy consumption, but also increase occupant comfort, health and safety by maintaining appropriate temperature and humidity levels and eliminating the uncontrolled air leakage through the envelope that creates drafts and contributes to the formation of mold.

1 Fast facts on energy use, ENERGY STAR® http://www.energystar.gov/ia/business/challenge/learn_more/FastFacts.pdf
2 Energy Efficiency Retrofits for Commercial and Public Buildings Office, Educational, Retail, and Other Key Segments and the Effects of Performance Contracting, ESCOs, LEED, and Energy Star, Pike Research, 2009
3 Energy Efficiency in Buildings—Transforming the market, World Business Council for Sustainable Development (WBCSD), 2009
4 Unlocking Energy Efficiency in the US Economy, McKinsey Global Energy and Materials (McKinsey & Company), 2009
5 Energy Efficiency Retrofits for Commercial and Public Buildings Office, Educational, Retail, and Other Key Segments and the Effects of Performance Contracting, ESCOs, LEED, and Energy Star, Pike Research, 2009
6 Fast facts on energy use, ENERGY STAR® http://www.energystar.gov/ia/business/challenge/learn_more/FastFacts.pdf
7 Energy Efficiency in Buildings—Transforming the market, World Business Council for Sustainable Development (WBCSD), 2009
8 Unlocking Energy Efficiency in the US Economy, McKinsey Global Energy and Materials (McKinsey & Company), 2009

The reduced energy consumption is calculable, but what about increased rates of tenant retention, or the ability to attract top-notch talent? A 2007 green retrofit survey of architects, business executives (including C-level titles), engineers and others found that[9]:

- 93 percent reported greater ability to attract talent
- 81 percent saw greater employee retention
- 87 percent reported an improvement in workforce productivity
- 75 percent saw an improvement in employee health

These same improvements can also contribute to reduced maintenance costs. Often they involve the upgrade or replacement of older, sometimes failing systems to newer equipment that requires less maintenance while using less energy. Other times, actions taken to reduce energy consumption—such as stopping uncontrolled air leakage or installing a high-performance roofing system—also slow or halt the deterioration of building materials through moisture damage.

Improving the performance of commercial buildings also includes improving their resistance to severe weather. The National Oceanic and Atmospheric Administration (NOAA) reports that hurricanes making landfall account for average insured losses of about $5.2 billion per year in the United States[10].

Ecological Impacts and Opportunities

The environment and the issues surrounding it are at the forefront of the collective attention span.

Existing commercial buildings are responsible for 17 percent of annual greenhouse gas (GHG) emissions in America[11], totaling approximately 990 megatons of carbon dioxide equivalent (CO_2e) in 2008, expected to rise to 1,220 by 2020 in a business-as-usual scenario[12].

Most of that carbon footprint is attributable to buildings' consumption of fossil fuel energy during operation. Based on energy usage, opportunities to reduce GHG emissions are most significant for space heating, air conditioning, lighting, and water heating—and given the durable nature of buildings, the greatest potential for GHG reductions resides mostly with the existing building stock (although new construction projects can and should be optimized for low carbon impact).[13].

No matter which side of the climate change debate you stand on, there are proven business benefits to reducing the carbon footprint of your building portfolio, even during an economic downturn.

Analysis conducted in 2009 by global management consulting firm A.T. Kearney showed that companies with established and recognized sustainability practices are outperforming their peers that are not committed to sustainability during the current economic crisis. Across the 99 companies included in the analysis, the performance differential worked out to 10 percent over three months, and 15 percent over six months. This differential translates to approximately $650 million in market capitalization per company[14].

Year	Property Damage (million $)	Crop Damage (million $)	Total Damage (million $)
2000	8.10	0.10	8.20
2001	5,187.80	2.70	5,190.50
2002	1,104.40	278.00	1,382.40
2003	1,879.50	40.80	1,920.30
2004	18,901.00	667.30	19,569.10
2005	93,064.40	2,075.20	95,139.60
2006	2.40	43.30	45.70
2007	38.80	0.01	38.80

Source: http://www.economics.noaa.gov/?goal=weather&file=events/hurricane

Upgrading commercial buildings to withstand high winds and windborne projectiles, storm surges and flooding can help to reduce and/or prevent much of the economic impact related to severe weather events—damage to structures, increased insurance rates and loss of business productivity for days, weeks or even months after a storm. Again, many of the tactics employed to improve severe weather resistance can also contribute to improved energy performance and occupant satisfaction levels.

A positive corporate social responsibility profile and the accompanying positive public relations can help attract and retain tenants seeking to do business with companies holding similar values, while marketing a building based on its sustainable attributes can raise its value.

According to a 2008 CoStar study[15], LEED buildings command rent premiums of $11.24 per square foot over their non-LEED peers and have

[9] *The dollars and sense of green retrofits*, Joint study by Deloitte and Charles Lockwood, 2008
[10] http://www.economics.noaa.gov/?goal=weather&file=events/hurricane
[11] Fast facts on energy use, ENERGY STAR® http://www.energystar.gov/ia/business/challenge/learn_more/FastFacts.pdf
[12] *Unlocking Energy Efficiency in the US Economy*, McKinsey Global Energy and Materials (McKinsey & Company), 2009
[13] *Towards a Climate-Friendly Built Environment*, Pew Center on Global Climate Change, 2005
[14] *Green Winners: the performance of sustainability-focused companies during the economic crisis*, A.T. Kearney, 2009
[15] Newly Released Studies Confirm Energy Savings Significant in LEED, ENERGY STAR Buildings, USGBC press release, 2008, http://www.usgbc.org/Docs/News/NBI percent20and percent20CoStar percent20Group percent20Release percent20040108.pdf

3.8 percent higher occupancy. Rental rates in ENERGY STAR® buildings represent a $2.38 per square foot premium over comparable non-ENERGY STAR buildings and have 3.6 percent higher occupancy. ENERGY STAR buildings were found to sell for an average of $61 per square foot more than their peers, while LEED buildings were found to command $171 more per square foot.

Pending government mandates, proposed cap-and-trade schemes and emerging carbon markets also provide incentives for reducing GHG emissions.

Improving the performance of existing buildings also has significant potential to reduce waste. Over 136 million tons of building related construction and demolition debris are generated by the United States in a single year.[16] Upgrading existing buildings instead of demolishing and constructing new buildings can divert a substantial amount of that waste.

Societal Impacts and Opportunities

The social side of improving the sustainability of existing commercial buildings may seem like the hardest to quantify in terms of business benefits, yet aspects such as improved employee productivity, increased health (and an accompanying reduced risk of litigation), as well as the larger-scale societal protection afforded by severe weather resistance, all have a direct impact on profitability.

Raising the performance of existing commercial buildings includes affording people safe, healthy, comfortable places in which to work, learn, play, shop and worship. Take the example of urban heat island effect. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). This phenomenon is largely caused by the absorption of solar heat by the dark surfaces of buildings, hardscaping and infrastructure.

Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality and water quality[17]. Increased daytime temperatures, reduced nighttime cooling, and higher air pollution levels associated with urban heat islands can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality[18].

Heat islands can also exacerbate the impact of heat waves, which are periods of abnormally hot, and often humid, weather. Sensitive populations, such as children, older adults, and those with existing health conditions, are at particular risk from these events[19].

Excessive heat events, or abrupt and dramatic temperature increases, are particularly dangerous and can result in above-average rates of mortality. The Centers for Disease Control and Prevention estimates that from 1979–2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States. This figure exceeds the number of mortalities resulting from hurricanes, lightning, tornadoes, floods, and earthquakes combined[20].

Poor indoor air quality, mold infestations and ‘sick building syndrome’ have made headlines in recent years, mainly for the massive litigation they have engendered. These problems—and the lawsuits—are often the direct result of compromised building performance.

The term “sick building syndrome” (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified[21]. The complaints may be localized in a particular room or zone, or may be widespread throughout the building.

A 1984 World Health Organization Committee report suggested that up to 30 percent of new and remodeled buildings worldwide may be the subject of excessive complaints related to indoor air quality (IAQ)[22]. Often this condition is temporary, but some buildings have long-term problems. Frequently, problems result when a building is operated or maintained in a manner that is inconsistent with its original design or prescribed operating procedures[23].

Severe weather damages structures and displaces people. It shuts down businesses—not only for the duration of the storm, but also for the immediate period of time following the event. Commercial buildings often serve as temporary refuges for evacuees, or staging centers for first responders. It is therefore imperative that these facilities weather the storm to the extent that they can afford appropriate refuge or effective platforms from which emergency services may respond to the needs of the affected community.

16 *High Performance Green Building: What's it worth? Investigating the Market Value of High Performance Green Buildings*, Theddi Wright Chappell, Managing Director, Cushman & Wakefield Washington Valuation Services, Capital Markets Group, National Practice Leader, Sustainability Valuation and Advisory Practice and Chris Corps, Principal of Asset Strategics; Co-founder, Vancouver Valuation Accord, 2009

17 http://www.epa.gov/heatisland/

18 http://www.epa.gov/heatisland/impacts/index.htm

19 http://www.epa.gov/heatisland/impacts/index.htm

20 http://www.epa.gov/heatisland/impacts/index.htm

21 http://www.epa.gov/iaq/pubs/sbs.html

22 http://www.epa.gov/iaq/pubs/sbs.html

23 http://www.epa.gov/iaq/pubs/sbs.html

2.0 Assessing the barriers and opportunities

The wholesale improvement of the sustainability and performance of America's existing commercial building stock would require the removal of several significant barriers and a holistic approach. Even a minor upgrade to a single structure can often be fraught with hurdles and conflicting motives.

These hurdles include[24]:

- Conflicting priorities and benefits between owners and occupants
- Elevated payback periods beyond the expected 3.6 years typical of most commercial building owners
- Capital constraints for both energy end-users and upstream financers
- Lack of information or awareness of key energy efficiency measures and how to deploy them

For example, in a tenant-occupied building, investments in energy efficiency upgrades are less likely to be made if the tenants pay directly for their own energy consumption. There may be little or no incentive for the building owner in this case, as the energy savings are passed directly to the tenants, making recovering the cost of the improvements difficult without a rent increase. However, if the same improvements are made in response to occupant complaints about thermal comfort, the building owner's incentive is clear: tenant retention.

Lack of awareness is often a key stumbling block—not everyone in the decision-making value chain understands how building performance improvements work and where the opportunities might reside within a particular building in a portfolio. In these cases, the project champion may face an uphill battle within the organization. However, increasing emphasis in the boardroom on corporate social responsibility and environmental stewardship may start to evolve into support for tangible sustainable performance improvement projects, provided a business case can be made.

There is still a long way to go. The 2009 Energy Efficiency Indicator from Johnson Controls and the International Facility Managers Association (IFMA), a survey of professional members of IFMA and a panel of company executives such as CEOs, COOs and general managers, sheds light on some of the most significant perception gaps in the value chain.

Topic	IFMA Members	Executive Panel
Energy management extremely/very important to company	73 percent	52 percent
Review energy forecasts monthly	39 percent	19 percent
Have buildings with green elements but no certification	54 percent	34 percent
Capital availability as top barrier to capturing energy savings for company	37 percent	44 percent
Payback/ROI as top barrier to capturing energy savings for company	31 percent	17 percent

Some of this lack of awareness or understanding of the benefits may also be attributed to past experiences tainted by projects not living up to potential, whether the result of over-promising of unattainable performance levels, faulty installation of prescribed tactics, systems or components, lack of proper maintenance or even 'greenwash' or exaggerated environmental claims.

The perceived premium cost and extended payback periods of building performance improvements are significant hurdles. Businesses, especially in tougher economic times, tend to concentrate on short-term investment horizons and lowest-first-cost procurement practices. Repair or replacement of systems or building components may be deferred due to budget constraints until the situation becomes critical and the project becomes an imperative for continued operation. The system or component is then replaced with the lowest-first-cost option—or with a system or product almost identical to the failed one out of familiarity—and the window for performance optimization is often missed.

[24] *Unlocking Energy Efficiency in the US Economy*, McKinsey Global Energy and Materials (McKinsey & Company), 2009

Yet upgrading to higher-performing systems or components may not be as costly as many assume. Studies have shown that incorporating 'green building best-practices' increase cost by about seven percent, comparable to the five percent premium commanded for current life-safety best-practices.[25] The key difference is that many of the sustainability best-practices will pay for themselves over time. The tolerance for longer payback periods remains the variable.

Examining the lifecycle cost is often an effective way to overcome perceived cost and payback barriers. Lifecycle costing is gaining traction in many organizations, especially in government agencies. This procurement practice evaluates the cost of a product, system or component throughout its complete service life—from first cost through installation, use and maintenance, removal and disposal and/or recycling.

Lifecycle cost procurement is often used to identify solutions that offer the greatest overall value—often by raising the overall performance of the building and providing return on investment (ROI) through increased energy efficiency, durability and occupant satisfaction.

A tactic for overcoming cost, payback and expertise hurdles is collaboration with an Energy Service Company (ESCO). Born out of the energy crisis of the 1970s, ESCOs develop, install, and arrange financing for projects designed to improve the energy efficiency and maintenance costs for facilities over a seven- to 20-year time period. ESCOs generally act as project developers for a wide range of tasks and assume the technical and performance risk associated with the project. When an ESCO undertakes a project, the company's compensation, and often the project's financing, are directly linked to the amount of energy that is actually saved.

ESCO projects are usually comprehensive, employing a wide variety of measures to achieve energy savings that often include high-efficiency lighting, high-efficiency heating and air conditioning, efficient motors and variable speed drives, centralized energy management systems and building shell upgrades—tactics that can require larger initial capital investments and offer longer payback periods.

Government policy plays a significant role in removing or reducing barriers to improving the performance of existing commercial buildings. Mandates are in place for minimum performance requirements for Federal government buildings, and many State governments and agencies are following suit. These mandates are meant to not only demonstrate leadership in energy and environmental management, but to provide living proof of the success of retrofit best-practices. Over time, they may also contribute to reduced costs for higher-performing materials, systems and components through supply and demand mechanisms.

The American Institute of Architects (AIA) argues that a significant government investment in the private sector is required to stimulate the economy. In its proposal document, The Two-Year, Nine-Million-Jobs Investment (The 2030 Challenge Stimulus Plan), under Architecture 2030, the organization states:

> *"Because the private building sector represents 93% of total U.S. building stock, and building construction alone accounts for approximately 10% of the U.S. GDP, the private building sector is the key to reviving the U.S. economy. Investing $192.47 billion ($96.235 billion each year for two years) in the private building sector to provide a 'housing mortgage interest rate buy-down' and a 'commercial building accelerated-depreciation program' for buildings that meet the energy reduction targets of the widely adopted 2030 Challenge will create, in just two years, over 9 million new jobs and $1 trillion in direct, non-federal investment and spending while opening up a new $236 billion renovation market that could grow to $2.6 trillion by 2030, and over $5.47 trillion by 2069. This Plan pays for itself annually through the new tax base created and can be implemented quickly through existing federal programs…Only 5.8% of homes and 3.1% of commercial buildings, i.e. just 5% of total U.S. building stock, would need to participate in the Two-Year, Nine-Million-Jobs Investment Plan to create these massive economic benefits."*[26]

Some government incentives for energy efficiency upgrades are available at present, thanks in large part to the American Recovery and Reinvestment Act of 2009 (ARRA), also known as the economic stimulus package. Under the Act, funding awarded to Energy Efficiency and Conservation Block Grant (EECBG) recipients—including states, cities, towns and tribes—may be used to develop and deploy energy efficiency incentive programs for commercial and residential buildings at the local level. $3.2 billion was allotted to the EECBG program under the ARRA, including $454 million for the new 'Retrofit Ramp-Up' program, intended to pioneer innovative models for rolling out energy efficiency to hundreds of thousands of homes and businesses in a variety of communities.

For access to other incentives, the *Database of State Incentives for Renewable Energy* (DSIRE, www.dsireusa.org) is a comprehensive source of information on state, local, utility, and federal incentives and policies that promote renewable energy and energy efficiency.

Government-funded incentives may provide the carrot, but government mandates provide the stick. Passed by the U.S. House of Representatives in June 2009 and currently before the Senate, the American Clean Energy and Security Act of 2009 (ACES) includes provisions for raising

[25] *Energy Efficiency in Buildings—Transforming the market*, World Business Council for Sustainable Development (WBCSD), 2009
[26] *The Two-Year, Nine-Million-Jobs Investment (The 2030 Challenge Stimulus Plan)*, American Institute of Architects (AIA), Architecture 2030, 2009

the performance of commercial buildings under *Title II Energy Efficiency, Subtitle A—Building Energy Efficiency, Sec 202 Building retrofit program*.

The Act's provisions include[27]:

- The development of performance-based building codes intended to reduce building energy use by 30 percent relative to a comparable building constructed in compliance with the baseline code
- The development of a performance-based building retrofit program that determines building energy efficiency success based on actual measured savings after a retrofit is complete, as evidenced by energy invoices or evaluation protocols
- The creation of the Retrofit for Energy and Environmental Performance (REEP) program to facilitate the retrofitting of existing buildings across the United States to achieve maximum cost-effective energy efficiency improvements and significant improvements in water use and other environmental attributes
- The mandate that building retrofits conducted under the REEP program utilize roofing materials with high solar energy reflectance to reduce energy consumption within the building, increase the albedo of the building's roof, and decrease the heat island effect in the area of the building, without reduction of otherwise applicable ceiling insulation standards, unless inappropriate due to green roof management or solar energy production
- The creation of financial rewards for success, including the following for commercial building retrofits:
    - $0.15 per square foot of retrofit area for demonstrated energy use reductions from 20 percent to 30 percent
    - $0.75 per square foot for demonstrated energy use reductions from 30 percent to 40 percent
    - $1.60 per square foot for demonstrated energy use reductions from 40 percent to 50 percent
    - $2.50 per square foot for demonstrated energy use reductions exceeding 50 percent

Also referred to as the 'Waxman-Markey Bill' and best known for its intention to establish a greenhouse gas (GHG) cap-and-trade scheme, ACES is expected to be the subject of fierce debate in the U.S. Senate.

[27] *H. R. 2454 American Clean Energy and Security Act 2009*, Calendar No. 97, 111TH CONGRESS, 1ST SESSION, IN THE SENATE OF THE UNITED STATES, received and read the first time JULY 6, 2009 (digital document certified by Superintendent of Documents <pkisupport@gpo.gov>, United States Government Printing Office with a valid certificate issued by GeoTrust CA for Adobe)

3.0 Commercial building retrofit best practices

There are many approaches and tactics that can be employed when it comes to improving building performance. Some are easy, quick and cost little to achieve. Others require more effort and moderate investment. And at the top of the best-practices scale in terms of effort, expertise, investment and results is the comprehensive, whole-building performance retrofit.

Low Effort, Low Cost Measures
The first, simplest and often lowest-cost step to improving the performance of existing commercial buildings is to ensure optimized operational and maintenance (O&M) protocols are established and followed[28].

Activities intended to change occupant behaviors for demand-side energy management can also be quite cost-effective, although often short-lived. Leadership, esprit de corps, rewards for positive behavior and the prevention of the perception of inconvenience resulting from the behavior change are essential ingredients for success[29].

Mid Effort, Moderate Investment Measures
Incremental steps toward improved building performance can be achieved as building systems or equipment require replacement, simply by selecting replacement solutions that offer reduced energy consumption, longer life expectancy with less maintenance, a lower environmental impact, enhanced occupant comfort, health and safety or all of the above. An example might be choosing ENERGY STAR-rated products over conventional options.

The Green Globes® for Continual Improvement of Existing Buildings (CIEB) tool aids commercial building owners and property managers in the evaluation, documentation and improvement of the environmental performance of commercial buildings by providing options when considering capital improvements and allowing building attributes and features to be benchmarked and rated.

When taking incremental steps toward building performance improvement, Green Globes-CIEB—which complements the Building Owners and Managers Association (BOMA) Energy Efficiency Program (BEEP)—provides reports that can help evaluate opportunities to benefit from energy savings, reduced environmental impacts, integrated corporate goals and practices and lower maintenance costs.

Many of these incremental steps can provide payback in the desired four- to five-year timeframe and the higher-performing option can often be accommodated within existing budgets or at a slight premium.

Comprehensive, Whole-Building Performance Retrofits
Often the domain of Energy Service Companies (ESCOs), these projects require significant expertise and effort, as well as investment. Fortunately, the ESCO model includes financing options and many incentive programs support the whole-building retrofit model because it offers increased opportunities for measurability and deeper reductions in energy consumption while also protecting occupant health and safety.

The goal of a whole-building retrofit project is to identify and address the full range of retrofit opportunities applicable to an individual building, as well as considering interactive effects among system components or building systems[30].

The recognition of the concept of the building-as-a-system, and that the performance (or lack of performance) in one system has an affect on the performance (or lack of performance) of the other systems, is fundamental to this approach. These systems consist of the building envelope or shell—roof, walls and fenestration—the heating, ventilation and cooling equipment, lighting and other plug loads, and the building occupants and their behaviors. These systems and their interaction also represent the greatest performance improvement opportunities[31].

A whole-building retrofit project begins with retrocommissioning. In new construction, commissioning is the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs. Retrocommissioning is the same systematic process applied to existing buildings that have never been commissioned to ensure that

[28] *Architect's and Engineer's Guide to Energy Conservation in Existing Buildings Volume 2 - Energy Conservation Opportunities*, U.S. Department of Energy, 1989
[29] *Energy Efficiency in Buildings—Transforming the market*, World Business Council for Sustainable Development (WBCSD), 2009
[30] *Comprehensive Commercial Retrofit Programs: A Review of Activity and Opportunities*, American Council for an Energy-Efficient Economy, 2005
[31] *Architect's and Engineer's Guide to Energy Conservation in Existing Buildings Volume 2 - Energy Conservation Opportunities*, U.S. Department of Energy, 1989

their systems can be operated and maintained according to the owner's needs.[32]

The retrocommissioning process should measure HVAC performance levels, lighting system performance and supplemental plug load. Infrared imaging technology can be used to inspect the building envelope for air migration pathways, thermal breaks and evidence of moisture inside wall cavities or in roof decks.

The result is a baseline of complete building performance, as well as the identification of specific areas requiring improvement in order to achieve desired performance levels. Some of the tactics prescribed will be lower-cost, higher-rate-of-return, while others will be higher-cost solutions with longer payback periods. Bundling these measures into a single project can help ensure optimal building performance, taking into account the interaction between systems and the ability for lower-cost, higher-rate-of-return elements to help offset more investment-intensive elements.

Studies of early whole-building retrofit incentive programs show energy savings of 11 to 26 percent of pre-retrofit consumption compared to eight to 13 percent savings for comprehensive lighting retrofits that did not include other end-uses[33]. Results from one chiller retrofit program that included a comprehensive approach to install additional efficiency measures reported whole building energy savings of 14 percent at an average cost of $4.50 per square foot of floor space[34].

In addition to the more obvious energy conservation benefits presented by whole-building retrofits, these projects often include societal and environmental improvements such as the removal and disposal of hazardous materials such as asbestos and lighting ballasts that contain PCBs or light tubes that contain traces of mercury[35]. Moisture problems are often identified during the building envelope inspection, allowing for correction and prevention or abatement of mold infestations.

One of the points of a whole-building assessment is to identify and prioritize the needs of the specific building in question, however, key areas and tactics often include[36]:

BUILDING EQUIPMENT OPERATION

- reduce operating hours for HVAC, lighting and ancillary equipment such as elevators, escalators and other machines
  - adjust space temperature and humidity setpoints
  - lower heating and raise cooling temperature setpoints
  - lower humidification and raise dehumidification setpoints

BUILDING ENVELOPE

- reduce heat conduction through ceilings, roofs, walls and floors
  - insulate and install vapor barriers
  - reduce solar heat gain through roofs and install reflective roof surfaces
- reduce heat conduction, solar gain and long-wave radiation through glazing areas
  - install storm windows and/or high-performance, multiple-glazed windows
  - insulate movable or operable windows
  - install exterior or interior shading
  - use tinted or reflective glazing or films
- reduce air infiltration
  - seal vertical shafts and stairways
  - caulk and weatherstrip doors and windows
  - install revolving doors or construct vestibules

HEATING, VENTILATION AND AIR-CONDITIONING SYSTEMS

- reduce ventilation rates
- reduce the generation of indoor pollutants
- install air-to-air heat exchangers, air cleaners and/or local ventilation systems
- improve chiller efficiency
- improve boiler or furnace efficiency
  - isolate off-line boilers
  - install automatic vent dampers
- improve air-conditioner or heat pump efficiency
  - reduce energy used for tempering supply air
  - use energy-efficient cooling systems
- reduce distribution system energy losses
  - repair ducting and piping leaks
  - maintain steam traps
  - insulate ducts
  - insulate HVAC system pipes
- reduce system flow rates
  - reduce air flow rates in ducts
  - reduce water or steam flow rates in pipes
- reduce system resistance
  - clean air filters in ducts
  - remove scale from water and steam pipes
  - rebalance piping systems
  - rebalance ducting systems

WATER HEATING SYSTEMS

- reduce hot water loads
  - reduce hot water consumption
  - lower hot water temperatures
  - preheat feedwater with reclaimed waste heat
- reduce hot water heating system losses
  - insulate hot water pipes
  - insulate water storage tanks
- use energy-efficient water heating systems
  - install decentralized water heaters
  - use smaller water heaters for seasonal requirements

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32 *Building Upgrade Manual*, ENERGY STAR, http://www.energystar.gov/index.cfm?c=business.bus_upgrade_manual
33 *Comprehensive Commercial Retrofit Programs: A Review of Activity and Opportunities*, American Council for an Energy-Efficient Economy, 2005
34 *Comprehensive Commercial Retrofit Programs: A Review of Activity and Opportunities*, American Council for an Energy-Efficient Economy, 2005
35 National Association of Energy Service Companies (NAESCO), http://www.naesco.org/resources/esco.htm
36 *Architect's and Engineer's Guide to Energy Conservation in Existing Buildings Volume 2 - Energy Conservation Opportunities*, U.S. Department of Energy, 1989

LIGHTING

- reduce illumination requirements
    - clean and maintain systems
    - reduce illumination levels
    - reduce time of operation
    - use task lighting
- install energy-efficient lighting systems
    - use daylighting

POWER SYSTEM

- reduce power system losses
    - correct power factors
    - install energy-efficient transformers
    - install energy-efficient motors
    - replace oversized motors
    - use high-efficiency motors
    - use variable speed motors
- reduce peak power demand
    - use load-shedding
    - install a cogeneration system and/or cool storage system

MISCELLANEOUS

- use energy management and control systems
- use heat reclaim systems

It should be noted that not every building will require all of these tactics to achieve desired performance levels, and many of the tactics common to whole-building retrofits can be implemented separately as incremental steps to improving overall building performance and sustainability.

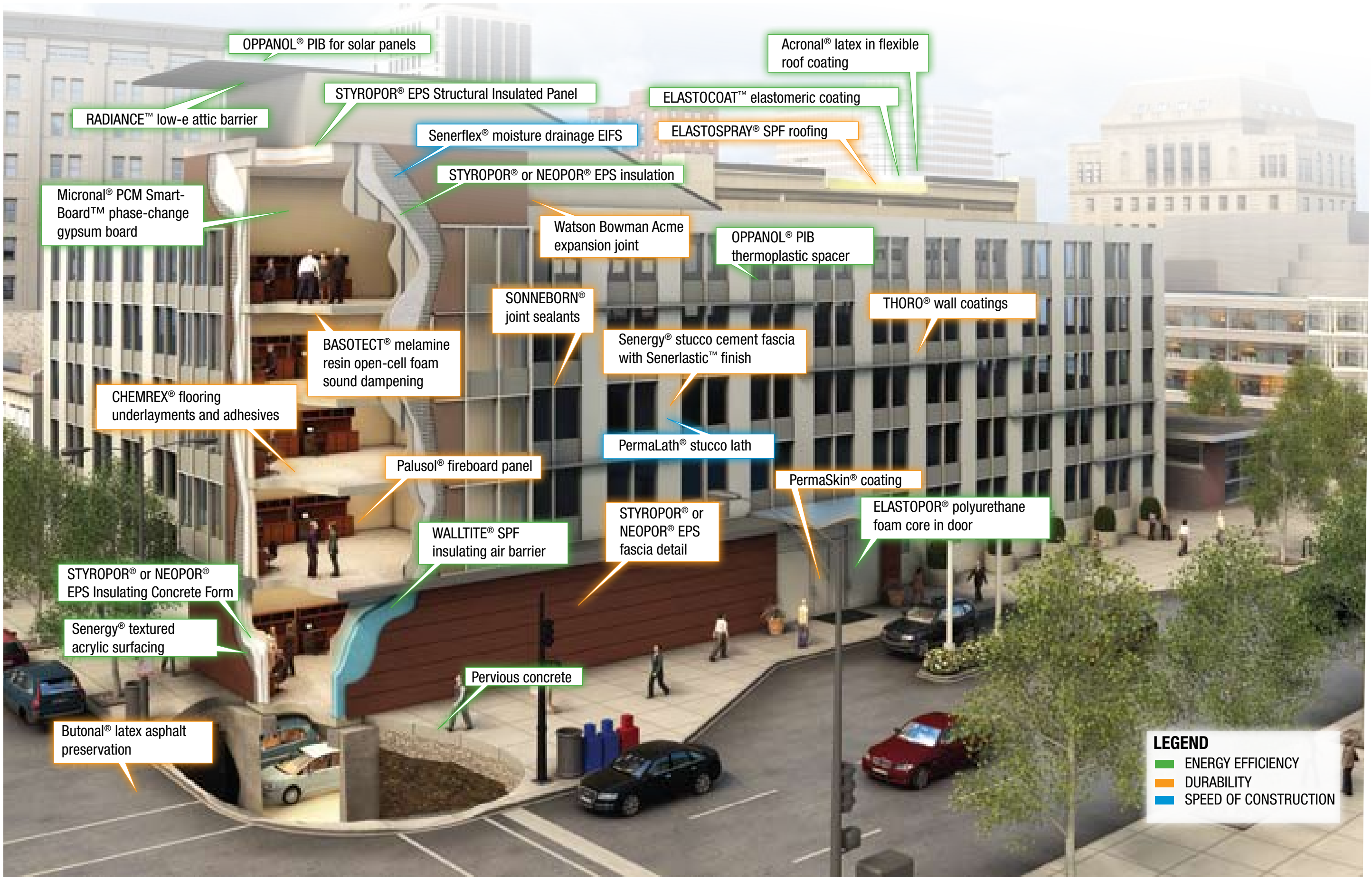
High-Performance Solutions

The array of products, systems and technologies available for use in commercial building retrofits is vast. Many have been used for decades, others are newer innovations. Examining attributes other than first cost—ones that address the impacts on the triple bottom line of economy, ecology and society—can help identify systems, products and components that contribute to overall building performance and save more money over the long term. Potential solutions might be evaluated based on performance attributes such as:

- potential contributions to energy efficiency over the short-, medium- and long-term
- potential reduction of urban heat island effect
- potential to enhance occupant comfort, health and safety
- expected service life
- expected maintenance requirements over the lifecycle
- severe weather resistance performance data
- environmental attributes such as locally manufactured materials, recycled content, use of rapidly renewable resources or reduced water consumption
- total lifecycle cost

Selection based on these criteria can often contribute more to overall building performance. Not all high-performance solutions will offer the lowest-first-cost option, but many provide greater return on investment and value over the medium- and long-term.

4.0 The chemistry of sustainable commercial building retrofits



This graphic is intended only to illustrate the breadth of the BASF construction portfolio and may not be an accurate design drawing of the structure. Not all materials and systems are necessarily compatible in combination with all other systems shown.

Chemistry is the building block of construction, found in almost every component of every structure. According to the American Chemistry Council (ACC), $14.8 billion worth of chemical ingredients were used for construction in 2007. The material demand (put-in-place product) for the entire construction sector was $498 billion, based on the $1.423 trillion total construction market in 2007. This means that the strategically relevant market for chemicals in construction is around $96 billion when substitution potential is considered.

Chemistry allows scientists to engineer products at the molecular level to optimize them for specific sustainable performance attributes. Superior insulation properties, extreme durability, reduced waste and improved air quality are just a few of the performance characteristics offered by construction materials that have been developed by chemists.

These materials can be used in almost every aspect of a sustainable commercial building performance retrofit. From building envelope systems to efficient HVAC system components, hardscaping and as ingredients in flooring, landscaping, electronics, plumbing and even renewable energy systems, chemistry helps enhance energy efficiency, durability and speed of installation while reducing environmental impact and lifecycle cost.

Building Envelope

The building envelope—the roof, walls, foundation and fenestration—plays a vital role in the performance of any structure. That role, quite simply, is to separate interior from exterior and provide the interior space with protection from external elements.

The envelope must control heat flow, moisture flow and air flow while providing structural integrity and protection from rain, snow, hail, wind, dust, pollutants, allergens and pests. A high-performance building envelope is defined by the system's ability to achieve these tasks.

Any compromise in the envelope system's performance impacts overall building performance. Insufficient insulation levels compromise the ability to control heat flow, reducing occupant comfort and causing the HVAC system to work harder. Gaps, cracks and holes in the envelope allow uncontrolled air leakage, a phenomenon where conditioned air escapes through the roof and walls, creating a burden on the HVAC system, uneven temperature and humidity levels and the potential for moisture-related damage and premature deterioration of building materials from moisture vapor transfer. A leaking roof, faulty rain screen or failed window frame can allow water intrusion—sometimes in significant quantities—which can cause structural damage and set the stage for mold, mildew and other threats to indoor air quality and occupant health.

Upgrading or restoring building envelope performance for an existing commercial building might entail adding insulation, sealing air migration paths, replacing windows, installing a new roofing system or any combination of these tactics. There are many high-performance products available choose from, all enhanced by chemistry.

High-Performance Roofing Systems

One of the highest-performing re-roofing options available today is spray-applied polyurethane foam (SPF). This system offers insulation values of 6.7 per inch and a seamless, monolithic application to reduce or eliminate thermal bridging, air leakage and moisture intrusion. When coupled with reflective, white acrylic coatings containing low or no volatile organic compounds, SPF systems help reduce urban heat island effect and satisfy rigorous air quality codes and standards in many jurisdictions.

This monolithic, spray-applied system offers industry-leading wind uplift performance because it has no edges for the wind to grab and lift. Its composition allows it to withstand hail storms and windborne debris.

SPF roofing systems are proven to provide a 4.5-year payback through energy savings[37] and because they are extremely lightweight, they can be installed directly over the existing roof substrate in 95 percent of retrofit situations, reducing or eliminating tear-off and disposal costs and diverting waste from landfill—making SPF a truly cost-effective, low-lifecycle-cost solution[38]. They offer a 20-year life expectancy with limited maintenance requirements and can be renewed indefinitely with simple recoats.

In addition to complete high-performance roofing systems like SPF, chemistry helps enhance the performance of many roofing assembly components and products.

Vegetative or 'green' roofing systems replace the vegetated footprint that was destroyed when the building was constructed. Performance attributes include stormwater management, energy conservation, reduction of urban heat island effect, increased longevity of roofing membranes and aesthetic appeal[39]. The plants included in a vegetative roofing system contribute to carbon sinking and can provide wildlife corridors, urban agriculture, and recreational areas[40].

An extensive green roof offers low maintenance landscaping consisting of shallow soil depths (< 6 inches or 150mm) with plant varieties restricted to primarily succulent plants, herbs and some grasses capable of withstanding harsh growing conditions. Extensive assemblies are typically un-irrigated and are constructed to achieve specific benefits. An intensive green roof requires regular maintenance and consists of deeper soil depths (> 10 inches or 250mm) with a wider variety of plant species. Intensive green roofs are typically irrigated and can furnish significant aesthetic and habitat value.

All vegetative roofing systems, whether extensive or intensive, require a high-performance waterproofing membrane as part of the complete assembly. These membranes are usually thermoplastic polyolefin (TPO) and/or composed of specialty plastics that include polyisobutylene (PIB), polyethylene terephthalate (PET, PETE), high density polyethylene (HDPE), vinyl (polyvinyl chloride or PVC) and low density polyethylene (LDPE)[41].

Many specialty coatings use the albedo effect to reflect solar heat away from the roof to help lower rooftop temperatures for improved building energy efficiency and reduced urban heat island effect. Traditionally these coatings are white in color, but new breakthroughs in the chemistry of heat management pigments are extending new aesthetic freedom to designers and building owners.

Among these innovations are Near Infrared (NIR) reflective pigments. Transparent NIR pigments can be formulated to reflect up to 45 percent of solar radiation, while NIR reflecting black pigments have solar reflectance of as much as 30 percent. By comparison, for traditional carbon black pigments, this value is less than five percent and white material has a long-term solar reflectance of 80 percent. In practical trials, the lower absorption of NIR reflecting black pigment relative to other black pigments results in a temperature decrease of up to 68 degrees Fahrenheit (20 degrees Celsius) on building surfaces.

High-Performance Walls

Insulation is a vital component of any wall system, enhancing thermal comfort and energy efficiency by controlling heat flow. Chemistry has brought about new innovations in insulation technologies that allow for the creation of walls with high R-values without adding significant thickness. In retrofit situations, this means insulation can be added to the insides of exterior walls during a major renovation with little or no compromise to the amount of interior space.

Expanded polystyrene (EPS) foam is a rigid insulation material offering an R-value of 3.85 per inch, making it among the most cost-effective options. Properly installed, it resists aging, and it is absolutely free from any tendency to rot or degrade.

New graphite-enhanced EPS insulation materials feature microscopic flakes of graphite that work as small mirrors to reflect heat and increase insulation value up to 20 percent, reducing the thickness of insulation needed for equal results. The insulation is attached to gypsum board and installed on the interior side of exterior walls to provide a one-step process for both interior finishing and enhanced insulation performance.

Spray-applied polyurethane foam insulation and air barrier materials come in two types—open-cell and closed-cell. Open-cell SPF offers an R-value of about 3.5 per inch, while closed-cell formulations offer R-values as high as 6.7 per inch coupled with industry-leading air permeance ratings. Both SPF types are applied on the interior side of external walls as a liquid that expands quickly to conform to irregular shapes with tenacious adhesion to the substrate.

37 *Texas A&M University Energy Data Measuring Cost Saving of Campus SPF Roofs Compared with BUR Roofs*, Gerald Scott, P.E., 1985
38 *Spray Polyurethane Foam Alliance Life Cycle Cost Study*, Michelsen Technologies, LLC, 2004
39 The Green Roof Research Program at Michigan State University, http://www.hrt.msu.edu/greenroof/
40 *Federal Green Construction Guide for Specifiers, SECTION 07 33 63 (SECTION 02930) – VEGETATED ROOF COVERING*, Whole Building Design Guide
41 *Federal Green Construction Guide for Specifiers, SECTION 07 55 63 (SECTION 07530) – VEGETATED PROTECTED MEMBRANE ROOFING,* Whole Building Design Guide

Vacuum insulated panels (VIPs) are an emerging technology that is starting to garner attention internationally. The units consist of a core panel enclosed in a vacuum sealed metallic or Mylar-foil™ envelope that provide an insulating value of three to seven times that of equivalent thickness of other insulation materials, such as rigid foam boards, foam beads, or fiber blankets. Currently, there are several types of core being developed for this use, including polystyrene, polyurethane, and a combination of silica and carbon. Although VIPs represent a promising, continuously improving technology, they are currently very costly. Additionally the impressive insulating values could be greatly diminished if the vacuum seal protecting the panels is breached. In a retrofit scenario, however, VIPs could represent an important, easy-to-install solution for areas where the building envelope needs energy upgrading, including interior walls and under the roofing deck.

Another emerging technology for improving thermal comfort and energy efficiency is a significant product upgrade for gypsum board—a revolutionary phase-change material called Micronal® PCM. With this new micro-encapsulation technology for interior building materials—such as plaster boards and wall boards—plastic capsules are filled with a special wax to absorb and release thermal energy by melting and solidifying in a controlled manner. The capsules increase the thermal capacity of building interiors and act to dampen temperature swings, reducing the heating and cooling load. Buildings constructed with Micronal modified plaster materials provide greater comfort for occupants. Energy modeling results indicate that the use of Micronal PCM can reduce air conditioning energy needs by up to one-third, depending on the overall design of the construction and the climate.

Chemistry also contributes to the performance of air barrier continuity component materials such as polyurethane insulating sealants, as well as caulks, weatherstripping and door seals.

When it is not feasible to retrofit a building's exterior walls with insulation from the inside—which is often the case because of interruption to workspace and timing issues—exterior insulating finishing systems (EIFS) can be used to vastly improve the thermal performance of a wall with relative ease and minimal disruption to existing building occupants.

EIFS are comprised of polystyrene insulation and reinforced synthetic stucco. Most systems also incorporate a liquid applied air/water-resistive barrier over the sheathing to further enhance thermal comfort and energy efficiency while reducing intrusive moisture concerns.

In 2007, the US Department of Energy (DOE), through the Office of Energy Efficiency and Renewable Energy's (EERE) Building Technologies Program, and the EIFS Industry Members Association (EIMA), sponsored a study, which was conducted by researchers at the Oak Ridge National Laboratory (ORNL). A building was constructed near Charleston in Hollywood, South Carolina, featuring panels with various wall claddings and assemblies. Each of the wall panels in which the claddings had been incorporated contained sensors that provided a full profile of temperature, heat flux, relative humidity, and moisture content. These sensors collected information 24 hours a day, 7 days a week, and transmitted the data to the ORNL research facility in Oak Ridge, Tennessee for analysis.

FIELD FACT:

Spray-Applied Polyurethane Foam (SPF) Roofing Systems

The main campus at Texas A&M boasts over 7 million square-feet of spray-applied polyurethane foam (SPF) roofing—almost no other system has been installed for the past 30 years. In 1974, dissatisfied with the performance of their traditional tar and gravel built-up roofing (BUR) systems, the university selected SPF because it is seamless, monolithic and fully adhered. And because it is lightweight, a complete tear-off of the existing BUR could be avoided.

In 1985, Gerald Scott, P.E., then in charge of roofing and energy conservation within the Physical Plant Department, announced another benefit the university had been receiving from the SPF roofs: energy savings. Scott monitored energy savings on 27 different buildings on the campus that had received an SPF roof from 1980 to 1984. The results showed the university was able to cover the complete cost of the roof application through energy savings in an average of 4.5 years.

The Mississippi Coast Coliseum, featuring its original SPF roof installed in 1977, has a long history of surviving storms. NOAA Coastal Services Center records show 15 named hurricanes and tropical storms hitting Biloxi from 1979 to 2005. The highest wind speed tracked was 115 miles per hour (mph) during Hurricane Frederic in 1979. Hurricane Katrina brought wind speeds as high as 110 mph to Biloxi.

NOAA also reports 28 severe hail events with hail stones at least one-inch in diameter, 28 tornadoes and 100 major thunderstorms with high winds in the Biloxi area between 1977 and 2006.

In all, the truly sustainable SPF roof on the Mississippi Coast Coliseum has survived more than 176 recorded days of severe weather in its 30+ years of service—an average of almost six days each year—without significant leaks or damage.

FIELD FACT:
High-Performance Windows

TRACO®, manufacturers of high-quality windows for more than 60 years, wanted to create a line of windows that addressed market demands for increased energy efficiency. The experts at TRACO realized that replacing the traditional metal spacer with a plastic version would make a significant difference. That's why for their NEXGEN™ Energy Windows they chose spacers produced by ADCO Global Inc., which are enhanced with polyisobutylene (PIB).

ADCO uses PIB as the primary sealant for its TPS system because it is flexible, reduces moisture infiltration and is resistant to UV radiation. The enhanced TPS spacers help increase energy efficiency up to 10 percent. They also provide design flexibility and long-term performance.

The real-world data gathered during the study demonstrated that EIFS clad wall assemblies with drainage outperform other typical exterior claddings (brick, stucco and cementitious fiberboard siding) during most of the year, making EIFS an excellent exterior cladding choice for achieving key building performance goals in a hot and humid climate.[42]

High-Performance Façade Restoration
Moisture penetration is one of the most critical challenges facing buildings today[43]. Interior or exterior, above grade or below grade, unprotected buildings suffer from water-induced damage. Deterioration and corrosion are caused by alkalis, salts, acids and mold. Waterproofing membranes and wall coatings, including epoxies and acrylic-polymers, use chemistry to protect brick, masonry and concrete surfaces from the damages of wind-driven rain, freeze-thaw cycles, and chloride ion intrusion.

The effects of corrosion, physical damage or a change of use can shorten the life of a building. Composite strengthening systems are designed for strengthening beams, slabs, walls and columns. Concrete protection and repair materials range from primers and bonding agents to engineered repair mortars formulated using chemistry to provide sustainable repairs that restore long-term integrity and strength to buildings and façades.

Steel reinforced concrete is an integral part of building structures. Unfortunately corrosion often compromises the integrity of many structures. Advanced corrosion control solutions using chemistry include high-quality carbon fibers, E-glass fibers, and aramid fibers, as well as epoxy resins, all formulated to inhibit corrosion, extending the service life of buildings and enhancing safety.

EIFS are often used to refresh the look of a building's exterior and restore moisture resistance to the façade, while also allowing an upgrade to thermal performance with the addition of insulation value and, when required, an air barrier.

High-Performance Fenestration
While improved daylighting may improve worker productivity and reduce lighting costs, fenestration has been viewed by some as the weak link in a sustainable building envelope. Excessive solar gain in warm weather can place a burden on cooling systems, while lack of window insulation and the potential for thermal bridging in cold weather can place a burden on heating systems.

Restoration and window replacement is often driven by moisture ingress. Moisture damages interior finishes and can lead to mold and mildew. If moisture can get in the window unit or perimeter, so can air—increasing heating and cooling costs as well as exacerbating mold and mildew problems.

Moisture also leads to corrosion of reinforcing steel, contributing to deterioration of concrete and masonry. This then becomes a public safety issue.

Recent material advancements in window and skylight technologies help make the case that increased daylighting can be a truly energy efficient choice.

For a complete window replacement situation, high-performance windows that feature elastic, energy-efficient, warm edge thermoplastic spacer (TPS) technology featuring polyisobutylene (PIB) can make a significant contribution to a high-performance building envelope. This warm edge system functions as a thermal break, which reduces the transfer of heat between conductive materials by sealing the edges of gas-filled insulated glazing units. Warm edge TPS technology can improve the energy performance of a window unit by up to 10 percent. As an additional benefit, TPS is flexible, so windows are better able to accommodate stress from wind and impact, making the units less susceptible to shattering or losing their seal and insulating interior gasses.

For buildings with expansive glazing, exterior shading and control devices—such as light shelves, overhangs, horizontal louvers, vertical louvers, and dynamic tracking or reflecting systems—can be designed to reduce undesirable solar heat gain while providing diffuse natural interior daylighting.

Chemistry also contributes to economical options for glazing retrofits, including a wide variety of tints, metallic/low-emissivity coatings and fritting that are applied over existing glazing with little or no disruption of workplace activity. High-performance hybrid, urethane and silicone elastomer sealants ensure outstanding weatherproofing and protection against extreme elements.

[42] *Exterior Wall Cladding Performance Study*, Oak Ridge National Laboratory/EIFS Industry Members Association, 2008
[43] *Building Envelope Design Guide - Wall Systems*, Daniel J. Lemieux, AIA and Paul E. Totten, PE Wiss, Janney, Elstner Associates, Inc., Whole Building Design Guide 2009

Efficient Heating, Ventilation and Air Conditioning Systems
The efficiency of HVAC equipment is one of the greatest contributors to a sustainable commercial building performance retrofit. The HVAC system provides comfort conditioning, regulating temperature and humidity levels and providing adequate amounts of fresh air. It is worth remembering, however, that no HVAC system can operate at peak efficiency if the performance of the building envelope is compromised.

Upgrading the performance of the building enclosure reduces HVAC load, and in some cases may even allow for the specification of downsized mechanical equipment.

HVAC equipment should be afforded regular monitoring and preventative maintenance to keep it functioning properly, although older equipment may not be capable of performing at the same levels as newer, high-efficiency systems.

New or old, mechanical equipment needs insulation to operate at peak efficiency. For existing systems, sealing and insulating ducts in situ can help reduce system energy loss and increase thermal comfort for occupants. Use temperature, thermal conductivity, density, specific heat, thermal diffusivity, alkalinity or ph, compressive resistance, flexural resistance, linear shrinkage, water vapor permeability and water absorption are all characteristics that should be taken into account when selecting an insulation material for mechanical equipment[44].

Chemistry contributes to several types of insulation suitable for use in HVAC equipment, including[45]:

- Elastomeric
- Polystyrene
- Polyisocyanurate
- Polyurethane
- Phenolic
- Melamine
- Polyethylene/Polyolefin
- Polyimide

Melamine resin open-cell foam insulation materials are perhaps best-known for their use in acoustic panels, but are gaining in popularity for use in HVAC equipment because of their ability to reduce mechanical system noise to enhance occupant comfort while still offering industry-leading high-heat performance and fire resistance.

Chemistry also contributes to high-performance plastics used in mechanical system manufacturing, including polyethylene terephthalate (PET), thermoplastic polyester (PBT) and polyamide.

FIELD FACT:
Exterior Insulating Finishing Systems (EIFS)

After Category 5 Hurricane Floyd hit the Bahamas in September 1999 with punishing winds of 155 miles per hour (mph) the five-tower, 2,300-room Atlantis, Paradise Island hotel remained standing. The hotel/casino had been clad two years earlier with 425,000 square feet of exterior insulation and finishing system (EIFS). To fabricate special design elements, the installers used insulation board ranging from 0.75 to 14-inches thick.

After the hurricane, hotel officials said, “there was zero damage to the exterior, with minor damage to the roof and ornamentation. The exterior insulation performed as designed.” By using adhesive versus traditional mechanical means to attach the wall system, the structure was able to withstand wind speeds of more than 200 mph. Its continuous fiberglass reinforcing mesh, available in five weights, also protected walls against impact damage.

Advanced Hardscaping
Extending a commercial building retrofit to include hardscaping elements can elevate the project into true sustainability by helping to control stormwater run-off. Many commercial properties include significant amounts of hardscaping—parking lots, walkways, patios and other outdoor areas for use of occupants.

Pervious pavement technologies—including pervious concrete and pervious asphalt—play a significant role by providing uniform distribution of run-off into vegetated areas to keep the water from directly entering the storm drain network, reducing run-off volume and promoting distributed infiltration[46].

Pervious concrete is a mix of portland cement, coarse aggregate, water and admixtures. Because there is little or no sand in the mix, the pore structure contains many voids that allow water and air to pass through. Chemical admixtures are used to enhance these formulations

[44] *Mechanical Insulation Design Guide - Materials and Systems*, National Mechanical Insulation Committee (NMIC), Whole Building Design Guide, 2008 http://www.wbdg.org/design/midg_materials.php

[45] *Mechanical Insulation Design Guide - Materials and Systems*, National Mechanical Insulation Committee (NMIC), Whole Building Design Guide, 2008 http://www.wbdg.org/design/midg_materials.php

[46] *Low Impact Development Technologies*, Anne Guillette, LEED AP, Whole Building Design Guide, 2008 http://www.wbdg.org/resources/lidtech.php

to improve ease of installation, including increased working time with improved concrete flow. The admixtures also increase compressive strength.

Chemistry as an Ingredient in Other High-Performance Retrofit Products

As mentioned at the opening of this section, chemistry can be found in almost every aspect of a sustainable retrofit. Sometimes the chemistry is harder to identify, because it is a hidden ingredient in products used to enhance overall energy efficiency, durability, speed of installation, environmental responsibility and lower lifecycle cost, such as:

- High-strength adhesives and sealants that emit low or no volatile organic compounds (VOCs) for enhanced indoor air quality
- Cement modification, concrete admixtures and efflorescence control for increased durability with reduced maintenance
- Sounds absorption insulation for enhanced occupant comfort
- Resilient and aesthetically pleasing flooring and carpet options
- Low-maintenance, long-life-expectancy decks, railings and fencing materials
- Durable, insulated garage and human-entry doors
- Adhesives, sealants and coatings used in renewable energy technologies
- High-performance plastics for safe electronics and durable plumbing applications

A Note on Emerging Technologies

No discussion on the chemistry of sustainable construction and retrofit products would be complete without a brief reference to new innovations. The combination of energy efficiency and renewable energy technologies is changing the way we think about buildings. Two game changers that are in development currently are nanotechnology insulating foams and organic solar cells.

Nanotechnology insulating foams, also known as nanofoams, represent the next generation of insulating materials. The prefix *nano* describes an order of magnitude—one nanometer being one billionth of a meter. This is about the length of five to 10 atoms arranged end-to-end. If a meter is the planet Earth, a nanometer is a tennis ball.

Nanotechnology describes the targeted and controlled development, manufacture and use of structures, materials and systems in magnitudes smaller than a hundred nanometers.

One example of current nanofoam technology available in the market is in the area of polycarbonate skylights and curtain walls. This silica-based nanofoam insulation improves the insulating value of these units by as much as five times, without the need for a vacuum seal.

The material’s physical characteristics limit its applications but scientists are currently working on non-silica based nanofoams that will deliver equivalent or greater insulating values while providing durability and wide-scale availability. For example, researchers are working on ways to transform current standard carbon-based insulations—such as EPS and polyurethane—into nanofoams. This innovation could significantly reduce heat conduction to less than half of that observed with conventional materials. These early stage nanofoams could be used to improve the overall performance of vacuum insulated panels, since they retain greater insulating value than traditional materials if the fragile vacuum seal is breached.

Organic photovoltaic technology includes solar cells based on organic semi-conductor materials, such as pentacene, polyfluorenes, and PCBM (phenyl-C61-butyric acid methyl ester), that replace the traditional silicon materials used today.

One of the biggest advantages of the emerging organic solar photovoltaics is that they can be mass produced, unlike silicon-based solar cells. However, organic solar materials still need to achieve higher solar energy conversion efficiency and increased durability before they are can gain traction in the mainstream.

Organic solar cell technology offers thinner, more flexible panels that can be incorporated into windows, exterior wall cladding and roofing materials, transforming passive systems into active, energy producing systems. Once this market is fully developed, organic photovoltaic systems may very well pave the way for sustainable and competitive energy production globally.

5.0 The role of The Chemical Company

BASF - The Chemical Company - is at the forefront of the sustainable building and retrofit industry. Given the impact chemistry has on the development and production of high-performance, sustainable solutions, it's not surprising that BASF is a leader in the construction industry. With more than 600 products serving 75 construction product categories, BASF offers the broadest portfolio of products used directly on construction sites, or integrated into other products, to improve the performance of construction and retrofit projects.

The company embraces sustainable development as a global core strategic guideline. The balance of social responsibility, environmental stewardship and profitable business growth is seen as a precondition to long-term success.

The construction product portfolio is recognized as increasingly important to the company's own sustainability goals, as well as to the business success of its customers.

Carbon Balance 3:1

The construction sector contributes about 22 percent to global GHG emissions. Considerable GHG mitigation potential is associated with the construction sector, the biggest lever being the opportunity to increase the energy efficiency of buildings during the use-phase.

BASF is committed to climate protection, including the efficient use of energy and raw materials in production processes and the creation of products that enable customers to reduce their own greenhouse gas emissions. The groundbreaking 2008 Carbon Balance report compares the greenhouse gas emissions created during the manufacture of BASF products with the emissions savings realized by their use. Believed to be the first report of its kind in industry, the results, confirmed by the Öko-Institut in Freiburg (Germany), show that BASF products—including insulation materials and other construction solutions—can save three times more greenhouse gas emissions than the entire amount caused by the production and disposal of all BASF products.

The analysis, based on 2006 production, focuses on BASF's chemical business and takes into account emissions from sourcing raw materials, production, product use and disposal.

Activity	Emissions (m tons CO_2e / year)[47]
Raw materials and precursors	28
Production (includes own power and production plants and emissions from the generation of electricity and steam by the company's energy suppliers)	25
End-of-life product disposal (assumed worst case = all incinerated)	34
TOTAL	**87**
Product use: Construction industry (Emissions saved through use of BASF insulation materials worldwide)	***-140***
Product use: Automotive industry (Emissions saved through use of plastics instead of metal, fuel additives)	-30
Technology transfer to emerging economies (industrial applications, etc.)	-82
TOTAL	**-252**

47 *Verified by Öko-Institut in Freiburg (Germany), 2008*

BASF insulation products help improve building energy efficiency to the extent that their use saves 140m tons of GHG emissions each year, more than compensating for the company's carbon footprint from operations.

Innovation, Product Development and Measurement Tools
With a suite of tools and resources, as well as access to extensive R&D facilities at home and around the world, BASF works toward continuous improvement for construction solutions. To develop technologies that help reduce maintenance, energy consumption, carbon footprint and waste sent to landfills. Technologies that improve the comfort, health and safety of occupants and reduce operating and lifecycle ownership costs.

Eco-Efficiency Analysis
Analysis beats greenwash. Scientific measurement is the only way to accurately document the true impact of construction products over the entire lifecycle. That's why BASF developed the award-winning, third-party validated Eco-Efficiency Analysis. To harmonize ecology and economy, it assesses the lifecycle of a product or manufacturing process from the "cradle to the grave" in five categories:

- Resource utilization
- Energy consumption
- Emissions to air, water and soil
- Toxicity potential
- Misuse and risk potential

The purpose of the Eco-Efficiency Analysis is to enable scientifically accurate comparisons of similar products or processes. This involves carrying out an overall study of alternative solutions to include a total cost determination and the calculation of ecological impact over the entire lifecycle.

The BASF Eco-Efficiency Analysis process has won three major awards of interest to the building and construction industry to-date: the *Design for Sustainability Award* (Society of Plastics Engineers), the *Presidential Green Chemistry Challenge Award* (U.S. Environmental Protection Agency), and the *Best Sustainable Practice Award in the Sustainable Research, Development, Construction Process and Demonstration* (Sustainable Buildings Industry Council).

More information on this science-based tool can be found at www.basf.com/sustainability

Total Cost of Ownership Tool
The BASF Total Cost of Ownership (TCO) analysis is another powerful tool that evaluates the cost—including raw materials, labor, manufacturing, energy, waste, capital and environmental health and safety (EHS) programs—of using one product and compares it to alternative products.

TCO analysis often brings out the less obvious ownership costs that might otherwise be overlooked in making purchasing decisions or budget plans. Often one product may have a higher initial purchase price, but its total cost of ownership is lower due to reduced waste, reduced energy consumption or lower maintenance costs.

Credentials for Leadership—Translating Sustainability to the Bottom Line
BASF is the world's leading chemical company. Its portfolio ranges from oil and gas to chemicals, plastics, performance products, agricultural products and fine chemicals. As a reliable partner, BASF helps its customers in virtually all industries to be more successful. With its high-value products and intelligent solutions, BASF plays an important role in finding answers to global challenges, such as climate protection, energy efficiency, nutrition and mobility. BASF has more than 97,000 employees and posted sales of $92.28 billion (€62 billion) in 2008. BASF shares are traded on the stock exchanges in Frankfurt (BAS), London (BFA) and Zurich (AN).

BASF Corporation, headquartered in Florham Park, New Jersey, is the North American affiliate of BASF SE, Ludwigshafen, Germany. BASF has more than 15,000 employees in North America, and had sales of approximately $17.5 billion in 2008.

Not just a leader in its industry, BASF is a global leader in sustainability and corporate social responsibility, committed to constant improvements in safety, protection of health and environmental conservation.

That's why we created the role of Global Climate Protection Officer. In both 2008 and 2009, BASF was ranked first among companies in the materials sector on the Carbon Disclosure Leadership Index, an honor roll for corporations addressing the challenges of climate change and carbon disclosure practices. The Carbon Disclosure Project represents some 475 global institutional investors, with more than $55 trillion in assets under management. As an independent not-for-profit organization, CDP collects key climate change data from more than 1,550 major corporations around the globe.

BASF is included in the Innovest Global 100 list—among the world's most successful companies in the areas of environmental protection, social affairs and corporate governance. BASF is also listed on the FTSE4Good Index and Storebrand SRI Funds.

In 2008, BASF was named the leading chemical company in the Dow Jones Sustainability World Index (DJSI World), recognized for its climate strategy, its environmental and social reporting and for developing innovative and eco-efficient products. 2009 marked the ninth consecutive year BASF has been included in the DJSI World rankings. BASF also earned the top rating of 100 percent in the 2009 Corporate Equality Index (CEI), an annual survey administered by the Human Rights Campaign (HRC) Foundation.

Already a supplier to the majority of leading building product manufacturers, BASF will not only continue to develop sustainable building materials, it will lead innovation in the industry. We will continue to work with industry stakeholders—from building owners, facility managers and design professionals to governments, code officials and building material manufacturers—to develop more solutions that help make construction projects more energy efficient, durable and faster to build.

BASF is a proud sponsor of and contributor to the Urban Land Institute Study *Retrofitting Office Buildings to be Green and Energy-Efficient: Optimizing Building Performance, Tenant Satisfaction, and Financial Return.*

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We make a lot of the products you buy better.®

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BASF is the world's leading chemical company: The Chemical Company. Its portfolio ranges from oil and gas to chemicals, plastics, performance products, agricultural products and fine chemicals. As a reliable partner, BASF helps its customers in virtually all industries to be more successful. With its high-value products and intelligent solutions, BASF plays an important role in finding answers to global challenges, such as climate protection, energy efficiency, nutrition and mobility. BASF shares are traded on the stock exchanges in Frankfurt (BAS), London (BFA) and Zurich (AN).

Further information on BASF is available on the Internet at www.basf.com.

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