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ASTHMAGENS IN BUILDING MATERIALS: THE PROBLEM & SOLUTIONS
ASTHMAGENS IN BUILDING MATERIALS: THE PROBLEM AND SOLUTIONS

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ABSTRACT:
Asthma is a complex, heterogeneous disease, often of multifactorial origin. Asthma rates in the USA have been rising since at least 1980. These rates are rising despite the proliferation of asthma control strategies, including indoor air quality programs. The Centers for Disease Control (CDC) reported that the number of people diagnosed with asthma grew by 4.3 million during the last decade. Nearly 26 million people are affected by chronic asthma, including over eight million children. As asthma affects more people, new strategies need to be considered. Among asthma risk factors, health organizations have identified hundreds of substances that can cause the onset of asthma. Many of these asthmagens are common ingredients of building products like insulation, paints, adhesives, wall panels and floors. This paper identifies asthmagens found in building products, how people can be exposed to these substances, and what is known and yet-to-be known about the impacts of these exposures. Key strategies to minimize exposures to asthmagens in building materials include understanding the composition of building materials; using product ingredient disclosure tools such as those recognized in LEED v4; and, modifying product certification standards, restricted substance lists, indoor environmental testing protocols, and green building incentives.

(Keywords: asthma, respiratory, health, buildings, protocols, IAQ, materials, isocyanates, formaldehyde, phthalates, polyurethane, insulation, PVC, flooring, certifications, FEMA, Katrina)

THE POST-KATRINA ASTHMA DISASTER
The Gulf Coast region understands the relationship between building materials and asthma. After Hurricanes Katrina and Rita struck in 2005, FEMA awarded $2.7 billion in contracts to shelter displaced residents. By August 2006, FEMA purchased 144,000 trailers and mobile homes.[1] A human-made health disaster ensued.

Connections between building materials, formaldehyde air emissions, and asthma were well established when FEMA put the Katrina trailers out to bid.[2] Formaldehyde resins bind composite wood casework, flooring, and wall panels. In 1992, the California Air Resources Board identified formaldehyde resins in these products as major sources of formaldehyde in indoor air. But FEMA’s bidding process did not consider the potential health impacts of bringing these materials into a hot and humid climate where formaldehyde is more readily volatilized.

A meta-analysis of seven studies in homes and schools from several different countries concluded that asthma risk in children increased 3-17 percent for every 10 Gg/m3 [8.1 parts per billion (ppb)] increase in formaldehyde in indoor air. In these studies, formaldehyde levels varied from very low to > 80 Gg/m3 (65 ppb).[3]

A U.S. Centers for Disease Control (CDC) study of Katrina FEMA trailers found formaldehyde well above these levels. The mean for the 519 tested trailers was 77 ppb.[4] In some, air concentrations exceeded 300 ppb. The most common unit - Gulfstream - had a median concentration of 111 ppb, almost seven times the national median of 17 ppb. Using the meta-analysis’ correlation rate, children living in the Gulfstream FEMA trailers had a 35% to 200% elevated risk of having asthma. In a federal health survey of FEMA trailer residents, 31% of the participating children reported having a diagnosis of asthma, nearly three-fold higher than the prevalence of childhood asthma nationally (11% in 2010).[5, 6]

Department of Homeland Security (DHS) Inspector General Richard Skinner reviewed the situation. “All of the units were some form of manufactured housing and therefore tended to have more of the manufactured wood products that can emit formaldehyde gas,” he reported. And the FEMA contracts “did not contain protections against excessive formaldehyde concentrations.”[7]

PATHWAYS FOR EXPOSURE TO ASTHMAGENS IN BUILDING MATERIALS

DHS Inspector General Skinner laid bare this reality: “Although workplace standards and recommendations for allowable exposures to formaldehyde have been implemented to protect workers who are exposed to formaldehyde, there is far less guidance as to what levels should be avoided in residences.”

Similarly, authoritative lists of asthmagens are based largely on studies involving worker exposures—hence the commonly used term “occupational asthma.” However, the extent to which chemicals known to cause occupational asthma may have similar effects within the general public, especially children, is often unclear for several reasons:

1. Occupational exposures are often much higher than residential exposures;
2. Dose-response levels are often not well enough established to allow extrapolation to low levels of prolonged exposure;
3. The importance of multiple factors in the origins of asthma, including co-exposure to allergens in residences, may make it more difficult to estimate the contribution of toxic exposures to asthma risk in homes compared to the workplace; and,
4. Occupational asthma generally affects adults whereas most asthma in the general public is among children, who are more vulnerable due to their smaller size and developing immune and respiratory systems.[8]

These challenges clearly pertain to chemicals in building products. Workers exposed to occupational asthmagens during product manufacture or building construction will be at increased asthma risk. But, after construction and building occupancy, exposure levels are generally unknown for most asthmagens.

Building occupants can be exposed to asthmagens in building materials by several pathways. Volatile and semi-volatile asthmagens may volatilize and be emitted into the air to be inhaled. Semi-volatile organic compounds (SVOCs) may migrate from products to dust particles by adsorption, which may in turn be inhaled, ingested, or come into contact with the skin. Non-volatile asthmagens on the surface of a building finish may be...
ASTHMAGENS IN BUILDING MATERIALS: THE PROBLEM AND SOLUTIONS

released as dust through degradation or abrasion and be picked up through the skin on contact.

Most concern about asthma risk associated with chemicals in building products in the general population has focused on volatile organic compounds (VOCs). Concern about exposure to less volatile compounds like phthalates and isocyanates has increased for several reasons:

1. Air monitoring and dust studies identify a number of SVOCs that may have originated in building materials;
2. Increasing numbers of epidemiologic studies show correlations between environmental levels of some SVOCs and asthma prevalence; and,
3. In vivo and in vitro laboratory studies have identified mechanisms by which some of these compounds may be related to asthma, including alteration in lung and immune system development after early life exposures.

EMERGING EVIDENCE OF HARM

Two SVOCs - isocyanates and phthalates - illustrate different aspects of the mounting evidence.

ISOCYANATES

Isocyanates are a family of highly reactive, low molecular weight (MW) chemicals, and are essential ingredients of polyurethane products like adhesives, furniture foam, and spray polyurethane foam (SPF) insulation.

A federal interagency air quality group notes that “agencies have received complaints regarding health effects including severe respiratory irritation, breathing difficulties, dizziness and nausea, resulting from the installation of SPF in homes.”[9]

EPA has an action plan to deal with isocyanates and is leading a multi-agency work group to address SPF.[10] In 2014, the California Department of Toxic Substances’ Safer Consumer Products initiative named SPF as one of its three initial “priority areas” due to its “potential for exposure to contribute to or cause significant or widespread adverse impacts.”[11]

Isocyanates are an established cause of occupational asthma through both allergic and irritant mechanisms.[12] They can cause contact dermatitis and lead to respiratory tract sensitization after skin exposure.[13] In a study in mice, isocyanate skin sensitization in females prior to mating resulted in airway inflammation and other features of an asthma phenotype in offspring.[14]

OSHA identifies isocyanates as respiratory, eye, and gastrointestinal irritants. “Hypersensitivity pneumonitis (inflammation in the lungs caused by exposure to an allergen)” has been reported in workers exposed to isocyanates, with symptoms experienced months or even years after exposure ends, according to the agency. “Deaths have occurred due to both asthma and hypersensitivity pneumonitis from isocyanate exposure.”[15]

Many of these polyurethane systems are mixed and applied on site in homes, schools, and offices. These are relatively unregulated and uncontrolled processes in widely varying environments. Exposures to isocyanates may also occur in people who enter a building before spray foam insulation is fully cured. In addition, a number of consumer products contain unreacted isocyanates, including adhesives and polyurethane coatings.[16] This means that skin or inhalation exposures may occur fairly regularly within the general population.

A recent EPA presentation notes that “SPF Insulation component chemicals can migrate to other areas of the building” and that isocyanates “can trigger severe or fatal asthma attacks in sensitized persons upon further exposure, even at very low levels.”[17]

PHTHALATES

Phthalates are synthetic diesters of phthalic acid used in many consumer products. These SVOCs may be released throughout the service life of building products such as such vinyl flooring, vinyl carpet backing, lacquers, flooring finishes, adhesives, and fluid applied floors. These emitted compounds become attached to household dust to which people are readily exposed.

The most common phthalates can be loosely grouped by lower and higher molecular weight (MW). These two groups differ in their industrial uses, environmental fate and transport, and exposure pathways. The dominant plasticizers used in building products like vinyl flooring are higher MW phthalates such as diethyl hexyl phthalate (DEHP) and benzyl butyl phthalate (BBP).

Exposures to phthalates are widespread and come from many sources.[18] This makes it difficult to quantify exposures that can be traced specifically to building materials. Inhalation, ingestion, and transdermal absorption are potential routes of exposure.

Air concentrations of phthalates are approximately 10 times higher indoors than outdoors.[19] Sources of phthalates that have been reported to affect indoor air phthalate levels are PVC building materials and furniture.[20] “Exposure to pollutants in the indoor environment has increased with improved insulation and reduced ventilation making many indoor environments act as concentrators of emissions from plastics, paints, and other building materials, reported Barro et al. in 2009. Pollutants like phthalates, they wrote, become concentrated in fine particulate matter with a weight of <2.5 micrograms; that is, dust.[21]

House dust can be inhaled or ingested. Guo et al. recently calculated that house dust could contribute 10% to 58% of total DEHP exposure to residents in a sample from Albany, New York. [22] Another study using biomonitoring data and modeling estimated that 39% of DEHP levels were attributable to indoor dust ingestion and 14% to inhalation.[23]

A public health study after Katrina took dust samples from children’s bedroom floors in FEMA trailers and found measurable levels of BBP and DEHP in all of them, with mean values of 175 ppm for DEHP and 59 ppm for BBP.[24] The levels of phthalates found in FEMA trailers are lower than those identified in older structures. Fromme et al in 2003 studied dust in German apartments and classrooms, and found mean concentrations of DEHP of 775.5 ppm DEHP and 86 ppm BBP.[25] In a recent study of phthalates in dust in 63 daycare centers, Fromme et al. reported median DEHP levels of 888 ppm.[26] They also measured phthalate metabolites in children attending those daycare centers. Using a cumulative risk assessment approach, they concluded that 20 percent of children had exposure levels to phthalates exceeding a safe reference dose. Rudel et al. in 2003 found a median value of 340 ppm DEHP and 45 ppm BBP in over one hundred dust samples from homes in Cape Cod.[27]
ASTHMAGENS IN BUILDING MATERIALS: THE PROBLEM AND SOLUTIONS (cont.)

PHTHALATES AND ASTHMA

Toxicology studies conducted both in vitro and in vivo animal models have proposed various mechanisms by which phthalates may exert their effect on allergies or airway inflammation.[28] Some phthalates can act as an adjuvant, magnifying the immune and respiratory system response to an allergen.[29] Phthalate exposure may also alter lung and immune system development.[30],[31] In rodent studies, DEHP exposure in utero is associated with delayed lung maturation.[32] The timing and route of exposure also appear to be important. (Similar exposure pathways and early life impacts are found in Bisphenol A Diglycidyl Ether (BADGE), another SVOC commonly used in building products. See Appendix B.)

Numerous studies show an association between exposure to phthalates and respiratory symptoms including asthma or wheeze.[33],[34],[35],[36],[37] The presence of PVC flooring and wall coverings is also associated with increased risk of childhood asthma.[38],[39],[40]

In summary, evidence of a causal relationship between exposure to phthalates and asthma continues to accumulate, particularly for the higher MW compounds commonly used in building products. Many observational studies are limited by cross-sectional design and the challenges of long-term exposure assessment for chemicals with relatively short half-lives. However, in vitro and in vivo laboratory studies have identified plausible mechanisms by which phthalates may influence the risk of allergies and asthma and add to the weight of evidence.

MENDING THE GAP IN BUILDING PRODUCT EVALUATIONS

Over the past two decades, green building advocates have developed powerful tools to test and certify the healthfulness of building materials. Asthma is not yet a major consideration of most programs, despite growing evidence that asthmagens are being released from building materials into indoor environments.

Many green building protocols and regulations reflect the times in which they evolved, when VOCs were considered the primary hazard from products. Regulatory requirements have led manufacturers of wet-applied products to publicly disclose and reduce VOCs since the 1970s. And green building IAQ certifications have measured individual VOC emissions from other non-wet applied products for over a decade.

These programs proved useful in significantly improving many building materials, which today generally contain and emit far fewer VOCs than they did in the 1990s.

More attention needs to focus on other health hazards. This came into sharp relief while the Healthy Building Network (HBN) researched its 2013 report, Full Disclosure Required: A Strategy to Prevent Asthma.[41] This report built from prior works such as Perkins + Will’s 2012 report, Environments: A Compilation of Substances Linked to Asthma, which identifies 374 known or suspected asthmagens in the built environment.[42] Full Disclosure Required narrows the focus to 50 substances, 38 of which are known asthmagens. Twelve chemicals are of emerging concern.

The authors cross-referenced three commonly referenced asthma lists – the AOEC Exposure Code List, the CSST List of Agents Causing Occupational Asthma, and the CHE Toxicant and Disease Database – with materials catalogued in HBN’s Pharos Building Product Library.[43],[44],[45]

Full Disclosure Required names twenty of these asthmagens to be of the highest priority, due to clear pathways for building occupants to be exposed to them after product installation and during normal use. Priority asthmagens include: acid aldehydes (two types); acrylates (four types); ammonium hydroxide; bisphenol A diglycidyl ether (BADGE); ethanolamines (three types); formaldehyde; isocyanates (six types); polyfunctional aziridine; and, styrene. Full Disclosure Required also recommends minimizing the use of phthalates.

Green building certifications standards do not consider most of these chemicals. Many asthmagens are not VOCs, and are not detected by current emissions testing protocols. As a result, high concentrations of asthmagens can be present in products that have earned low VOC-emissions certifications.

Chemical identification is essential for protecting human health. Most green building programs do not identify and therefore do not restrict most asthmagens. Appendix C (Asthmagens in Building Products: Identification by Relevant Standards) reveals:

• Twenty-three (46%) of the substances are not identified by four leading programs (Cradle-to-Cradle, Living Building Challenge, California 01350, and Greenguard Gold).

• California 01350 indoor air emissions testing looks for only three (3) of the substances (formaldehyde, styrene and toluene).

• Greenguard Gold looks for fourteen of these chemicals in its air emission tests. Cradle-to-Cradle and LBC product content requirements identify 11 and 17 of these substances, respectively.

• None of these programs screen for isocyanates or biocides like triclosan.

Gaps in coverage represent opportunities to extend the healthfulness of building materials to other substances of concern, including asthmagens.

Transparency and research deepen the awareness of material contents. Science is associating certain chemicals with emerging health impacts. Chemists and engineers are innovators who can reduce the impacts of products through green chemistry. And leading corporations are recognizing that the future of green building belongs to the triad of creativity, transparency, and healthfulness.
These efforts, bound by independently verified certifications, provide a strong platform for reducing exposures to asthmagens in building materials.

- **Standard-based certifications can help to prevent exposures to asthmagens by defining the product, setting conditions for its evaluation, and standardizing testing protocols.** The end product is a simple label or declaration indicating a specific product meets the standard. Qualified material selection choices can be identified via the standard’s product database or registry.

- **Standards can consider any substance in a product that can harm building occupants.** In the case of asthmagens, standards can be updated or created to recognize the low dose exposures that can cause the onset of asthma, recognizing that for many of these substances researchers have not been able to determine safe thresholds. Emissions based programs can complement their emissions testing protocols with content testing to support avoidance. They can draw from transparency efforts (like the Pharos Project, Declare, and the Health Product Declaration) to ensure that the tests search for any asthmagen known to be present in these products, even at trace levels.

- **Restricted substance lists that drive these certifications can be updated to include priority asthmagens.** New protocols may be developed specifically to address asthmagens or other substances of concern, and require testing for these substances. For example, the European Union this year launched a revised EU Ecolabel for Paints and Varnishes that quantifies and limits SVOC content. It caps SVOC content at 30 grams per liter (g/l) for white paint applied to interior walls, and 60 g/l for some other applications.[47] US-based IAQ programs do not yet quantify SVOCs as a whole.

- **Standards must be transparent.** The vast majority of today’s green building certification programs make their protocols freely available to the public. One notable exception: The Asthma and Allergy Foundation of America recently certified a line of vinyl flooring as “Asthma & Allergy Friendly.”[48] The certification’s standard is not posted on its website, and the foundation did not respond to this paper’s authors requests for information as of August 15, 2014.

While transparency is vital for understanding the potential hazards of a given product, standards can also protect intellectual property. If a standard and certification scheme is trustworthy, it may be generally assumed that the independently verified claims are accurate without full disclosure. The disclosure has been made to the certifier, who assures the conditions of the standard have been met.

- **Asthma prevention strategies can be applied, in turn, to the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) rating system,** which should reward projects that avoid introducing asthmagens into the indoor environment.

USGBC President and CEO Rick Fedrizzi told Greenbuild 2012 attendees, “When people doubt that we can improve health outcomes, we’re going to show them the drawers of unused asthma inhalers in green schools.” [49] The green building movement finds solutions. By focusing more of its collective resources – materials research, product testing, certifications and incentives – on asthmagens in building materials, it can solve this problem, too.

**ACKNOWLEDGEMENTS**

Charlene W Bayer, PhD, Senior Research Fellow, U.S. Green Building Council and Chairman and Chief Scientist at Hygieia Sciences LLC provided valuable insights, especially in identifying household dust studies.

Thanks to the Healthy Building Network research team for their considerable contributions to this paper, especially Sarah Lott (co-author of Full Disclosure Required) and Peter Sullivan; to Melissa Coffin, Susan Sabella, Tom Lent, and Bill Walsh for edits; and to HBN’s supporters and funders who make this work possible, including New York Community Trust, The John Merck Fund, the Passport Foundation, and the Forsythia Foundation.

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**REFERENCES**


ASTHMAGENS IN BUILDING MATERIALS: THE PROBLEM AND SOLUTIONS (cont.)


Asthmagens in Building Materials: The Problem and Solutions (cont.)

APPENDIX A.

BACKGROUND ON ASTHMA
Asthma is a complex and heterogeneous disease. Various combinations of genetic predisposition and exposures to environmental agents, including allergens, chemicals, psychosocial stress, and different dietary patterns, can result in the development of asthma. Airway narrowing and wheeze characterize asthma. Inflammation in the lungs is usually present although there is some variability in the remodeling of airways accompanying the disease.

We use term “asthmagen” to refer to a chemical that can initiate asthma onset in someone who did not previously have the disease. Exposures to asthmagens can combine with other risk factors to make the disease more likely. An asthma trigger is an environmental agent that can cause an asthma attack in someone who has the disorder.

Two kinds of asthma that can be related to chemical exposures:
1. One kind is allergic or sensitizer induced asthma; the other is
2. Irritant-induced asthma.
3. Sometimes they are mixed in a single person.

Allergic or sensitizer induced asthma involves an immune system response to the chemical exposure. If it’s not recognized early, the sensitization can become more widespread to include a number of additional chemical substances.

Chemicals may also contribute to the risk of sensitizer-induced asthma by serving as an adjuvant—an agent that boosts the response to an allergen, making sensitization more likely. For example, laboratory animal studies suggest that the plasticizer DEHP may act as an adjuvant, thereby enhancing the risk of allergic sensitization to an allergen.[1]

Irritant induced asthma can be caused by a single, fairly large exposure to the chemical irritant. Airway irritation is followed by airway narrowing and wheezing. This may then lead to reactive airway disease and more frequent wheezing episodes with an ultimate diagnosis of asthma.

APPENDIX A SOURCES:

APPENDIX B.

Bisphenol A Diglycidyl Ether (BADGE): Early life exposures
Bisphenol A diglycidyl ether (BADGE) is a member of the family of glycidyl ethers that have been widely used as components of epoxy resins for decades. In the built environment, they are found in high concentrations in epoxy fluid applied floors, adhesives and sealants, as well as paints, toys, compact discs, electronic equipment, and printed circuit boards. Volatilization and/or release of bisphenol analogues from these products are considered to be sources of contamination of indoor dust. [1]

BADGE and its hydrolysis products have been reported in indoor dust. Wang et al. in 2012 studied 158 dust samples from four countries. The study found mean concentrations of 2 to 3 parts per million (ppm) of BADGE and its hydrolysis products in indoor dust, and considered BADGE-based epoxy resin as a source.[2] Rudel et al. in 2003 found a median value of 0.821 ppm bisphenol A in 118 dust samples from homes in Cape Cod.[3],[4]

Workers who spray BADGE have elevated urinary levels of bisphenol A (BPA), which suggests that BADGE may generate BPA endogenously.[5] Exposure to BPA in the general population is widespread.[6] Dietary intake from food contamination is a major source, but dermal contact as well as indoor dust ingestion and inhalation contribute significantly. The estimated median daily intake of bisphenol analogues through dust ingestion in the U.S., China, Japan, and Korea was 12.6, 4.61, 15.8, and 18.6 ng/kg body weight/day, respectively, for toddlers and 1.72, 0.78, 2.65, and 3.13 ng/kg bw/day, respectively, for adults.[7]

Some of the highest levels of BPA reported in human specimens (8.3 ng/ml) occur in amniotic fluid between weeks 15-18 of pregnancy.[8] In some animal studies, developmental exposure to bisphenol A is associated with alteration of the immune response and in some cases, increased sensitization to allergens.[9],[10] In a laboratory study of mice, maternal dietary exposure to BPA during gestation and lacta-
tion resulted in increased allergic sensitization to an allergen (ovalbumin) and airway inflammation in newborn offspring.[11] In a similar study, after maternal exposure to BPA in drinking water during gestation and lactation, offspring were studied in adulthood after being on a BPA-free diet following weaning.[12] Allergic sensitization to ovalbumin in infancy remained increased in BPA-exposed animals without evidence of increased lung inflammation.

But not all studies in mice have similar findings.[13],[14] A recent study using a similar, widely used experimental model of asthma in mice concluded that the impacts of BPA on immune system development and allergic asthma response is dependent on timing and duration of exposure.[15] Lifelong exposure from birth, but not pre-natally, until the last antigen challenge increased inflammation in the lung, airway hyper-reactivity and antigen-specific serum IgE levels in OVA-sensitized adult mice compared to mice without BPA exposure.

A study in female non-human primates found that exposure to environmentally-relevant doses of BPA during late gestation accelerates secretory cell maturation in the proximal conducting airways.[16]

In one prospective cohort study of 398 mother-infant pairs, higher prenatal BPA exposure was associated with increased odds of wheeze in early life.[17] Another long-term prospective cohort study of children in New York found that urinary BPA concentrations at ages 3, 5, and 7 years were associated with increased asthma risk assessed at ages 5 to 12 years, whereas maternal gestational exposures had an inverse relationship to asthma risk.[18]

Collectively, these studies show that developmental exposures to BPA can alter both immune system and lung development in ways that may make asthma more likely. Some developmental periods appear to be more responsive than others, making the timing and duration of exposure important considerations.

### APPENDIX C.

#### ASTHMAGENS IN BUILDING PRODUCTS: IDENTIFICATION BY RELEVANT STANDARDS

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<td>Trimethylolpropane triacrylate (15625-89-5)</td>
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**GREEN BUILDING STANDARDS IDENTIFICATION**

- Global Automotive Industry Declaration Thresholds
- Cradle-to-Cradle (2012)
- Living Building Challenge (2014)
- California 01350
- GreenGuard Gold
## APPENDIX C.
### ASTHMAGENS IN BUILDING PRODUCTS:
IDENTIFICATION BY RELEVANT STANDARDS (cont.)

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<tr>
<th>Substance of Concern (CAS No.)</th>
<th>Related Building Materials</th>
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<td>Methylene Bisphenyl Diisocyanate (101-68-8)</td>
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<tr>
<td>Methylene diphenyl diisocyanate &amp; related compounds (26447-40-5)</td>
<td>SPF, thermal insulation, mineral board, composite woods, solid surfaces, high performance coatings, adhesives</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Toluene diisocyanate (26471-62-5)</td>
<td>Carpet backing</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Polymeric TDI (9017-01-0)</td>
<td>Cork flooring</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>1,6-Hexamethylene Diisocyanate (822-06-0)</td>
<td>Paints, Carpets (backing), Flooring finishes</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4,4’-MDI homopolymer (25686-28-6)</td>
<td>Spray foam insulation</td>
<td>None</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Diphenylmethane-2,4’-diisocyanate (2,4’-MDI) (5873-54-1)</td>
<td>Spray foam insulation, polyurethane carpet backing</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Polymeric MDI (9016-87-9)</td>
<td>Cork flooring, fluid flooring, engineered wood binder, adhesives, spray foam insulation, polyurethane carpet backing, underlayment</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>PHTHALATES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzyl butyl phthalate (85-68-7)</td>
<td>PVC flooring (sheet and VCT), floor- ing adhesives, PVC roofing membrane, carpet backing</td>
<td>0.01% (BGO); prohibited over 0.25%</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Di-(2-ethylhexyl) phthalate (117-81-7)</td>
<td>Roofing membranes, vinyl carpet backing, PVC flooring (VCT and sheet)</td>
<td>0.01% (BGO); prohibited over 0.3%</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Di-n-hexyl phthalate (84-75-3)</td>
<td>Vinyl composition tile</td>
<td>0.1% (Renault)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Dibutyl phthalate (84-74-2)</td>
<td>Flooring finishes, casework adhesive, lacquers</td>
<td>0.01% (BGO); prohibited over 0.25%</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>DiisoNonyl phthalate (28553-12-0)</td>
<td>Vinyl composition tile, vinyl carpet backing</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>DiisoNonyl phthalate (DINP-1, mixture of isomers as manufactured) (68515-48-0)</td>
<td>Carpet (backing), membrane roofi ng, VCT flooring</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Dicyclohexyl phthalate (84-61-7)</td>
<td>Methyl methacrylate flooring</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Diisodecyl phthalate (117-81-7)</td>
<td>Flooring adhesive, vinyl composition tile</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Di-n-octyl phthalate (117-84-0)</td>
<td>PVC membrane roofing</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>OTHERS</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonium hydroxide (1336-21-6)</td>
<td>Paints, adhesives</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Bisphenol A Diglycidyl Ether (BADGE, 1675-54-3 and 25085-99-8)</td>
<td>Adhesives, High Performance Coatings, Grouts and Mortars</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Formaldehyde (50-00-0, and various compounds)</td>
<td>Laminate, thermal insulation, mineral board, SPF, wallboard, engineered wood, acrylic/latex adhesives</td>
<td>Any level must be reported (GADSL 2014) prohibited over 0.1%</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Polyfunctional aziridine (64265-57-2)</td>
<td>Floor finish, high performance coating</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Styrene (100-42-5)</td>
<td>High performance coatings, polystyrene insulation, foam board insulation</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
## APPENDIX C.
### ASTHMAGENS IN BUILDING PRODUCTS:
#### IDENTIFICATION BY RELEVANT STANDARDS (cont.)

<table>
<thead>
<tr>
<th>Substance of Concern (CAS No.)</th>
<th>Related Building Materials</th>
<th>Auto Industry</th>
<th>C2C</th>
<th>LBC</th>
<th>O1350</th>
<th>GG GOLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biocides</td>
<td>G G G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzisothiazolin- 3-one (BIT) (2634-33-5)</td>
<td>Paints, adhesives</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Didecyl dimethyl ammonium chloride (DDAC) (7173-51-5)</td>
<td>Anti-sapstain treatments</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hexamethylenetetramine (100-97-0)</td>
<td>Preservatives</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Triclosan (3380-34-5)</td>
<td>Paints, carpets, engineered wood, ceramic tile</td>
<td>0.001% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Metal dusts</td>
<td>G G G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminum (dust) (7429-90-5)</td>
<td>Window frames, siding, board insulation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Aluminum oxide (dust) (1344-28-1)</td>
<td>Resins, finishes, grouts, laminate surfaces</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Chromium &amp; chromium compounds (dust) (7440-47-3; 18540-29-9 (Chromium VI))</td>
<td>Stainless steel; aluminum alloys; carpet backings (via fly ash filler)</td>
<td>0.001% (Renault) prohibited above 0.1%</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Cobalt &amp; cobalt compounds (dust) (7440-48-4)</td>
<td>Paints, flooring stains, fly ash, porcelain tile</td>
<td>0.001% (BGO)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Nickel &amp; nickel compounds (dust) (7440-02-0)</td>
<td>Wall guards; carpet backings (via fly ash)</td>
<td>0.001% (BGO)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Vanadium (dust) (7440-62-2)</td>
<td>Porcelain tile</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Zinc Oxide (dust) (1314-13-2)</td>
<td>Paints, carpet backing, glazes, adhesives</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Perfluorocarbons</td>
<td>G G G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perfluorooctanesulfonic acid &amp; salts (PFOS [C8], 1763-23-1)</td>
<td>Stain-blocking carpet treatments</td>
<td>0.001% (BGO); prohibited over 0.1% (Renault)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Perfluorooctanoic acid &amp; its salts (PFOA [C8], 335-67-1)</td>
<td>Stain-blocking carpet treatments</td>
<td>0.01% (BGO)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PerfluorohexaNoic acid (PFHxA [C6], 307-24-4)</td>
<td>Stain-blocking carpet treatments, grout</td>
<td>0.1% (Renault)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Others</td>
<td>G G G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic acid, glacial (64-19-7)</td>
<td>Silicone caulking, High performance coatings</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Bispheneol A (80-05-7)</td>
<td>High-performance concrete hardeners, fluid-applied flooring hardeners, epoxies, dry-erase paint</td>
<td>0.01% (BGO)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Colophony (gum rosin) (8050-09-7)</td>
<td>Linoleum and adhesives</td>
<td>0.01% (Renault)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Polyvinyl Chloride (9002-86-2)</td>
<td>VCT flooring, corner guards, ceiling panels, carpet backing, roofing membrane</td>
<td>0.1% (BGO)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Tall Oil Rosin Ester (8002-26-4)</td>
<td>Linoleum and adhesives</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Toluene (108-88-3)</td>
<td>Adhesives, lacquers, engineered wood (binder and finish), paint</td>
<td>0.1% (BGO)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Wood dust, esp. Western Red Cedar (No CAS No.)</td>
<td>Composite wood products and laminates</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
D08:
OVERCOMING CHALLENGES:
DEMAND RESPONSE &
PEAK LOAD REDUCTION
OVERCOMING CHALLENGES: DEMAND RESPONSE AND PEAK LOAD REDUCTION

AUTHORS:
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Courtney Yan | USGBC, Washington D.C., USA
Silia Kiliccote | Lawrence Berkeley National Laboratory, Berkeley, CA, USA
Ella Sung | Lawrence Berkeley National Laboratory, Berkeley, CA, USA
Mary Ann Piette | Lawrence Berkeley National Laboratory, Berkeley, CA, USA
James Fine | Environmental Defense Fund, Washington D.C., USA
Peter Sopher | Environmental Defense Fund, Washington D.C., USA
Mark MacCracken | CALMAC, Fair Lawn, NJ, USA

ABSTRACT:
Most green design professionals, building owners, and building operators place little importance on when they use electricity; however, this variable is critically important to the cost of energy, the efficiency of power generation and the stability of the electric grid. Classic demand response entails a signal from the utility to a customer to temporarily reduce electric usage by a certain time for a certain period; this can be done either manually or automatically, and a financial incentive is paid for this accommodation.

Demand response and permanent peak load reduction can reduce the magnitude of reserve requirements for traditional generation resources, enable low-cost integration of intermittent renewable generation resources, deliver bill savings to customers, and improve air quality. LEED v4’s new Demand Response (DR) credit is intended to reduce the load on the electric grid at peak through either temporary or permanent peak load reduction.

This paper evaluates building operators’ interest in and ability to participate in DR programs and facilitate cost-effective, large-scale deployments of DR. Results were obtained from studying nearly 100 commercial buildings in Las Vegas and southern California. Research questions address consumer energy use behaviour and barriers to participation, performance assessment and estimation in commercial buildings, customer financial analysis and cost-effectiveness, and system-wide impacts, including environmental and reliability impacts. Results of the study will guide the refinement of the LEED DR credit and develop a rich dataset on peak demand in buildings that did not exist in large scale.

We will share the research study findings and lessons learned when dealing with the challenging landscape of utility-customer interactions as well as the continued efforts to drive market transformation for the adoption of DR in commercial buildings.

(Keywords: buildings, demand response, automated demand response, peak demand, load shifting, load shedding)

INTRODUCTION

One of the hallmarks of LEED, or Leadership in Energy and Environmental Design, is the concept of integrative design, which encourages builders and architects to think beyond the walls of a building and consider the interconnection between building systems and the environment. Demand response (DR) is another step in this tradition, focusing on electricity use decisions - how much and when it is used - and the realities of energy generation and distribution.

Carefully planned and effectively deployed demand response can reduce the environmental footprint of electricity generation, transmission, and distribution systems, as well as the footprints of energy users and their vehicles. DR can provide emissions reductions and other environmental benefits that include, but are not limited to, the following:

• Relocating demand from peak to off-peak times and thus avoiding emissions from use of fossil fuel “peaker” power plants
• Reducing the size of the grid, including generation, transmission and distribution infrastructure, needed to meet system peak demand
• Integrating variable, renewable energy sources

The Demand Response Partnership Program (DRPP) is a collaborative effort between USGBC and Environmental Defense Fund (EDF), bringing together both sides of the energy grid to increase participation in demand response programs. DRPP connects utilities and technology solution providers with owners and managers of LEED registered and certified buildings.

By driving adoption of automated demand response (ADR) through the DR pilot credit and supporting research into the impacts of DR, the program seeks to facilitate stronger relationships between the energy and building communities, reduce dependency on fossil fuel peak generation, and address our electric grid infrastructure and reliability needs.

This paper describes the methodology for the evaluation of the DRPP and DR, and shares preliminary results.

LEED DR Credit

The Demand Response Pilot Credit, officially referred to as Energy & Atmosphere Pilot Credit 8: Demand Response (EApc8 or Pilot Credit 8), was introduced in July 2010. The credit was modified in March 2012, removing the option of using manual DR strategies to achieve DR load reductions, effectively requiring that qualifying new buildings have an Energy Management Control System or Building Automation System capable of automatically managing the building load without human intervention.

Pilot Credit 8 is applicable to all LEED rating systems except Commercial Interiors, Neighborhood Development, and Homes. To achieve the credit, project teams must design and have in place the equipment necessary to participate in demand response through load shedding or shifting; on-site electricity generation does not count towards this credit. There are additional requirements – based on building type – for determining peak demand, commissioning the DR equipment and processes, and performing measurement and verification of the DR reduction.

The credit language supports two cases: where there is an existing demand response program available and where a demand response program is not yet offered. In addition, existing buildings that have already addressed their peak electrical loads with active, permanently installed systems can attain the credit through permanent peak load reduction.

The introduction of the pilot credit represents the first time LEED has explicitly addressed issues related to electricity use beyond the walls of the project building in order to support grid reliability and optimize electricity generation, transmission, and delivery. This pilot credit supports the vision of a “smart” electricity grid

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that operates dynamically, reliably, efficiently, and in a way that engages and leverages real-time feedback to and from building owners and users in order to benefit owners, operators, occupants and broader society.

**METHODOLOGY**

The research methodology originally had three key elements: data gathering, infrastructure development for data sharing and storing, and data analysis [1]. Our analysis activities had three main focus areas: load impact, environmental impact, and perceptions towards demand response and the LEED DR Credit.

**LOAD IMPACT**

The amount of load reduction (kW) was calculated by comparing the actual DR event load with a baseline that estimates what loads would have been if there were no DR events.

Lawrence Berkeley National Lab (LBNL) previously developed a number of baseline models to estimate the demand savings from DR strategies [2]. Two baseline models were used to calculate demand reductions for this project:

- Outside air temperature regression (OATR) model
- “Ten-in-ten” (10/10) baseline model.

The OATR baseline model is the most accurate, least biased model and works best for weather-sensitive buildings. However, collecting weather data from a site or a location close to a site is cumbersome; therefore, the 10/10 baseline model, which uses average hourly load shape of the ten energy-consuming days during the 10 work days preceding the DR event of interest, is the baseline model preferred by utilities in California. Developing the 10/10 baseline does not involve collecting weather data, which simplifies the development process.

The demand savings estimates for most of the buildings that participated in this study are based on the baseline OATR model. If the model predicts a lower baseline than the actual demand for any given 15-minute or hourly period, this indicates negative demand savings. Negative demand savings are often found after a DR period as part of a “rebound” or recovery peak in which the HVAC system tries to bring the thermal zones back to normal conditions.

The evaluations performed include quantifying the demand savings in kilowatts (kW) at each site, the savings in whole-building power reduction by percentage, and the demand intensity (W/ft²). The demand savings are calculated by subtracting the actual whole-building power from baseline demand. The demand savings percentage is defined as the percentage of savings in whole-building power. The demand-savings intensity (W/ft²) is the demand reduction (W) normalized by the building’s conditioned floor area (ft²). We also use a scalar adjustment for the morning load. This methodology was utilized for the summer tests where the DR events took place in the afternoon.

Two utilities, actively involved vendors, and 25 LEED registered buildings participated in the load reduction analysis portion of the study. A summary of the data used for DR analysis is provided in Table 1:

- Building location, building use type, and whole building gross square footage (GSF)
- Demand response program in which the building participated (CPP: Critical Peak Pricing; DBP: Demand Bidding Program; DRC: Demand Response Contract; TA: Technical Audit; TI: Technical Incentive)
- Data available at the time of this paper including whole building energy use data in 15 minute intervals, submetered energy use data in 15 minute intervals, billing history and incentives received for participation in demand response, DR program information, and exit surveys.

### Table 1: Summary of Site Data

<table>
<thead>
<tr>
<th>Building</th>
<th>Location</th>
<th>Type</th>
<th>Whole Building GSF (approx)</th>
<th>DR program</th>
<th>Data Received</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Whole Building</td>
</tr>
<tr>
<td>215</td>
<td>Las Vegas, NV</td>
<td>Resort</td>
<td>1,143,000</td>
<td>mPowered</td>
<td>x</td>
</tr>
<tr>
<td>216</td>
<td>Las Vegas, NV</td>
<td>Office</td>
<td>211,700</td>
<td>mPowered</td>
<td>x</td>
</tr>
<tr>
<td>217</td>
<td>Las Vegas, NV</td>
<td>Office</td>
<td>274,000</td>
<td>mPowered</td>
<td>x</td>
</tr>
<tr>
<td>---</td>
<td>Las Vegas, NV</td>
<td>Public Assembly</td>
<td>98,300</td>
<td>mPowered</td>
<td>x</td>
</tr>
<tr>
<td>230/224/231</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>467,900</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>228</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>443,700</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>236/229</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>400,764</td>
<td>TA, DBP</td>
<td>x</td>
</tr>
<tr>
<td>235</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>444,000</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>234</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>331,200</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>237</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>333,200</td>
<td>TA, DBP</td>
<td>x</td>
</tr>
<tr>
<td>227/221</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>320,700</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>226/222/223/225</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>262,200</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>232/233</td>
<td>Irvine, CA</td>
<td>Office: Mixed Use</td>
<td>298,300</td>
<td>DBP</td>
<td>x</td>
</tr>
<tr>
<td>218</td>
<td>Visalia, CA</td>
<td>Higher Education</td>
<td>502,500</td>
<td>DRC</td>
<td>x</td>
</tr>
<tr>
<td>219</td>
<td>Tulare, CA</td>
<td>Higher Education</td>
<td>104,300</td>
<td>CPP</td>
<td>x</td>
</tr>
<tr>
<td>220</td>
<td>Hanford, CA</td>
<td>Higher Education</td>
<td>55,900</td>
<td>CPP</td>
<td>x</td>
</tr>
<tr>
<td>---</td>
<td>Newport Beach, CA</td>
<td>Office</td>
<td>329,500</td>
<td>TA, DBP</td>
<td>x</td>
</tr>
<tr>
<td>---</td>
<td>Santa Ana, CA</td>
<td>Office</td>
<td>198,200</td>
<td>TI, DBP</td>
<td>x</td>
</tr>
<tr>
<td>---</td>
<td>Orange, CA</td>
<td>Office</td>
<td>211,200</td>
<td>TA, TI, DBP, DRC</td>
<td>x</td>
</tr>
<tr>
<td>---</td>
<td>Irvine, CA</td>
<td>Office</td>
<td>567,500</td>
<td>DRC</td>
<td>x</td>
</tr>
</tbody>
</table>
In addition to the electric load data, the research team collected weather data. Some utilities already collect this data and use them to deliver certain analytic tools for their customers. In cases where the data were not available through the utility information system, the research team used the closest NOAA weather station data.

ENVIRONMENTAL IMPACT

The method to link the causal steps from emissions to impact generally falls within the modelling specialty of “integrated assessment” (see Figure 1). For electricity demand, a complete integrated assessment requires a multi-step model (or collection of linked models) capable of several computational steps:

- Linking electricity demand changes to power plant and motor vehicle emissions changes, typically using economic-dispatch electricity production simulation models.
- Representing emissions changes in air quality simulation and dispersion models to simulate downwind air quality outcomes.
- Estimating health effects associated with air quality outcomes using dose-response models.
- Monetizing health effects using econometric models.

For demand response, the two largest near-term impacts arise from reducing the magnitude and changing the timing of power plant and vehicular emissions that are known to be harmful to people and the environment [3,4,5]. The six principal or “criteria” air pollutants for which National Ambient Air Quality Standards exist are carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM), and sulfur dioxide (SO2). Toxic air contaminants, such as diesel fuel combustion exhaust, can also be influenced by smart grid; for example, enabling electric vehicles avoids toxic vehicular emissions in locations that are often very close to sensitive receptors, such as schools, hospitals and elderly residences.

Air pollution can be emitted primarily from sources, such as smokestacks, or formed secondarily in the atmosphere. “Primary” pollutants are emitted directly into the atmosphere (e.g. sulfur dioxide from the combustion of coal). However, “secondary” pollutants occur as the result of chemical and physical reactions in the atmosphere (e.g. smog), nonlinearly, as a consequence of emissions. Reduced air pollution may reduce the health effects of both primary and secondary pollutants, but calculating these benefits requires representation of atmospheric processes, hence the need for modelling.

To calculate the emissions footprint associated with the electricity use of an individual building, it is necessary to know the emissions intensity of generation sources that were contributing at a given time. All of the generation sources added up, weighted by their generation, can reveal an average emissions rate per kWh served (i.e. generation mix emissions intensity, GMEI). The GMEI can be used to characterize actual conditions in real-time and to forecast expected GMEI based on anticipated generation resources and forecasted demand. In its simplest form, a GMEI is a weighted average of emissions from the generation resources on the grid. This relationship is shown in Equation 1 for greenhouse gases and generation units.

The more specific, building-specific hourly GMEI for which we’ve solved for our analyses is shown in Equation 2. One way we use GMEI in this analysis is to calculate the 24-hour emissions impact of a building (see Equation 3). The longer version of this formula that disaggregates GMEI is shown in Equation 4. With this formula, we calculate the GHG emissions footprint of DR event days and corresponding baseline days. In comparing these two figures, we determine whether GHG emissions increased or shrunk on DR days relative to baseline days.

For the environmental impact portion, we studied 46 DR events across 4 sites in the Southern California Edison (SCE) territory: 12 for sites 224 and 227 and eleven for sites 234 and 237. There were 12 DR days; sites 224 and 227 participated in all, while 234 and 237 missed October 4th and August 21st, respectively. The hours for all 46 DR events were 2-6pm (see Table 2).

Figure 1: Integrated Assessment Model
OVERCOMING CHALLENGES: DEMAND RESPONSE AND PEAK LOAD REDUCTION (cont.)

Table 2: DR Event Location and Timing Considered for Environmental Impact Calculations

<table>
<thead>
<tr>
<th>DR Day (2013)</th>
<th>Site 224</th>
<th>Site 227</th>
<th>Site 234</th>
<th>Site 237</th>
<th># of Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>July 3</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Aug 21</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>---</td>
<td>3</td>
</tr>
<tr>
<td>Aug 28</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Aug 30</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Sept 4</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Sept 6</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Sept 13</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Sept 23</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Sept 30</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td>Oct 4</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>---</td>
<td>2-6 PM</td>
<td>3</td>
</tr>
<tr>
<td>Oct 17</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>2-6 PM</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total # of Events</strong></td>
<td><strong>12</strong></td>
<td><strong>12</strong></td>
<td><strong>11</strong></td>
<td><strong>11</strong></td>
<td><strong>46</strong></td>
</tr>
</tbody>
</table>

These data were used for conducting the following analyses:

- Hourly grid electricity generation for the entire summer of 2013, disaggregated by fuel source used. Data used in these analyses come from CAISO [6].
- Emissions factors (emissions per unit of electricity generated) for all fuel sources that supply the SCE grid. According to EIA SEDS 2012 data for California, less than 1% of electricity consumption comes from coal and petroleum combined [7]. We assume that all of California’s thermal emissions come from natural gas, and that 25% of natural gas plants are new combined cycle (CC), 25% are old CC, 25% are new spin cycle (SC), and 25% are old SC. Emissions factors for new and old CC and SC gas plants are the same ones used in a May 2014 Brookings Institution analysis, and they derive from EIA April 2013 data [8]. Furthermore, according to EIA 2012 SEDS data, thermal fuels sourced about 53.5% of California’s electricity consumption, so it is assumed that the emissions factor for “Imports” is 53.5% of the value for thermal. Accordingly, we use the following emissions factors: “Thermal” (996.875 lbs CO2/MWh) and “Imports” (532.8207 lbs CO2/MWh)
- Building-specific demand data for DR event days and baselines. These data were provided by SCE.

RESULTS

At the time this paper was completed, not all the data from all the sites were received and therefore a complete analysis of all sites was not possible. We present results from a subset of participating sites with data complete enough to demonstrate some of the methodologies. The research team is in the progress of developing reports for the participating utilities and expect to have all the data needed to complete the studies for all the sites.

LOAD IMPACT

We calculated DR savings for each building for each event they participated in and provided a summary of the results in Table 3 below.

We present the data in several formats: a) as a percent reduction from whole building power, b) DR savings density, and c) absolute savings. The min and max numbers are per event and average is the average of all the events in which each site participated. Depending on the program in which they enroll, there may be large differences in number of events.

There are several observations to note. First, while most literature suggests that 10% load reduction is an achievable goal for DR in commercial buildings, not all buildings in our study were able to achieve this level of reduction. In this sample, this is partly because some of the buildings did not implement DR in the entire facility; DR implemented in a small portion of the building systems may result in load changes not visible from the whole building meter.

Second, most minimum savings are negative. This means on some DR days, not only did the sites not save energy, they even consumed more. Automation of DR strategies can enhance the response by removing the manual aspect from the demand response. However, if there is no timely feedback, DR performance may deteriorate over time due to faults that may be happening in the building systems.

Figure 2 shows the demand profile of site 219 on a DR event day.

PARTICIPANTS PERCEPTIONS

The behavioural aspect of this research is anecdotal information collected from sites using surveys completed during participation in DRPP. The following surveys were developed:

- Non participant surveys to determine barriers and reasons for not participating
- Participant program selection surveys to compare and contrast different DR programs and various value propositions
- Customer awareness surveys to determine market awareness and perceptions
- Technology utilization surveys to assess technologies and usability of existing systems

The survey results will be summarized in a later paper.
The blue line is the measured demand on that day. Red and green lines indicate the two baselines calculated for this site. From the load, it looks like this building started their DR controls between 1 and 2pm to precool the building. During the DR period, the site allowed the room temperatures to increase by 4 degrees. Rooms that did not curtail loads include server and student learning rooms. At this site, we observe a new, small peak around 7pm.

The intent is to share load impact findings with the sites, collect information on their DR control strategies and automation systems, and discuss how to improve participation. DR control strategies for commercial buildings are well documented but their application is based on the particular capabilities of each building [9]. In addition, where there is multi-year data, we will study how the load shape over time changes and how this impacts DR savings [10].

Table 3: Summary of DR Performance of Sites (Subset)

<table>
<thead>
<tr>
<th>Building</th>
<th>% Whole Building DR savings</th>
<th>DR Savings Density (W/sqft.)</th>
<th>Absolute DR savings (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min.</td>
<td>max</td>
<td>ave.</td>
</tr>
<tr>
<td>224</td>
<td>59.13</td>
<td>69.90</td>
<td>67.20</td>
</tr>
<tr>
<td>228</td>
<td>15.95</td>
<td>48.50</td>
<td>39.35</td>
</tr>
<tr>
<td>234</td>
<td>-1.90</td>
<td>7.05</td>
<td>3.00</td>
</tr>
<tr>
<td>237</td>
<td>1.27</td>
<td>8.05</td>
<td>18.10</td>
</tr>
<tr>
<td>227</td>
<td>-1.40</td>
<td>7.00</td>
<td>3.00</td>
</tr>
<tr>
<td>226</td>
<td>5.40</td>
<td>14.70</td>
<td>11.55</td>
</tr>
<tr>
<td>232</td>
<td>3.20</td>
<td>22.15</td>
<td>16.45</td>
</tr>
</tbody>
</table>

Figure 2: Demand Profile of Site 219 on August 30, 2013
ENVIROMENTAL IMPACT

On the average DR event day, total load among the buildings studied was reduced by 596 KW, or 1.1%, below demand on the average baseline day. During DR event hours, 2-6pm, load was lower on the average DR event day than on the average baseline day. These statistics are segmented by building, month, and DR event day in Table 4.

Based on comparison of hourly load on DR event days to baseline days, we used three methods to calculate the emissions impact of DR event and baseline days:

• Method 1: Use the DR day’s average GMEI.
• Method 2: Use the baseline day’s GMEI.
• Method 3: When determining GHG emissions impact for DR days and baseline days, we use the average DR day GMEI for DR days and the average baseline day GMEI for baseline days.

Figure 3 depicts hourly emissions impact on the average DR event day relative to the average baseline day, using three different methodologies. Figure 4 shows daily emissions reductions on the average DR event day relative to the average baseline day, as calculated from three different methodologies. These figures show that methods (1) and (2) yield virtually identical results for both hourly and daily emissions reductions on DR event days compared to baseline days. Using method (3), however, there are more emissions on DR days relative to baseline days. For methods (1), (2), and (3), average daily emissions reductions on the average DR event day relative to the average baseline day are 0.0506 MtCO2e, 0.0482 MtCO2e, and (-0.3157) MtCO2e, respectively.

There are more emissions on DR event days relative to baseline days in method (3) because, as shown in Figures 5 and 6, the CAISO generation mix has a slightly higher percentage of both thermal and imported power on DR days (74%) than on baseline days (72%). In methods (1) and (2), however, baseline and DR day emissions are calculated using the same generation mix; there are fewer emissions on DR days because load is lower on these days.

Overcoming Challenges: Demand Response and Peak Load Reduction (cont.)

Further explaining why there are more emissions on DR days despite lower load when using method (3), Figure 7 shows that the generation mix emissions efficiency (GMEE), or power generation per emission (KW/MtCO2e), is lower on DR event days relative to baseline days during every hour of the day. The vertical red lines show the time period in which DR events take place. A lower GMEE on DR days means lower demand per emission, so lower efficiency. While DR event days have a lower GMEE at all hours of the day than baseline days, during the DR event hours, 2-6pm, GMEE trends slightly upwards on DR days whereas it trends downward on baseline days.

At the site level, average GMEE and GMEI at sites 224 and 227 are identical because DR events occur on the same days, so they have the same generation mix (see Figure 8). DR day GMEI relative to the baseline is higher than average for site 234 and lower than average for site 237.

Figure 10 depicts generation mix emissions intensity (GMEI), or emissions per unit of power produced (MtCO2e/GW). GMEI is the inverse of GMEE; so, a higher GMEI means higher emissions intensity and lower emissions efficiency. Figure 9 shows that GMEI is higher on DR days relative to baseline days during every hour of the day, with the peak at 1pm.
Table 4: DR Event Load Summary Statistics, Average by Building, Month, and DR Event

<table>
<thead>
<tr>
<th>DR Event Days</th>
<th>Demand Reduced on DR Days Relative to Baseline* Days (KW)</th>
<th>Ave. Daily Baseline* Load (KW)</th>
<th>% Demand Reduction on DR Days Relative to Baseline*</th>
<th>DR Day Demand Lower than Baseline* at 2-6pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVERAGE (All Events)</td>
<td>596</td>
<td>53,815</td>
<td>1.1</td>
<td>Yes</td>
</tr>
<tr>
<td>224</td>
<td>1,099</td>
<td>26,560</td>
<td>4.1</td>
<td>Yes</td>
</tr>
<tr>
<td>227</td>
<td>1,506</td>
<td>56,869</td>
<td>2.6</td>
<td>Yes</td>
</tr>
<tr>
<td>234</td>
<td>-488</td>
<td>112,835</td>
<td>-0.4</td>
<td>No</td>
</tr>
<tr>
<td>237</td>
<td>139</td>
<td>21,194</td>
<td>0.7</td>
<td>Yes</td>
</tr>
<tr>
<td>July</td>
<td>-1283.1</td>
<td>54,168</td>
<td>-2.4</td>
<td>No</td>
</tr>
<tr>
<td>August</td>
<td>2,185</td>
<td>59,575</td>
<td>3.7</td>
<td>Yes</td>
</tr>
<tr>
<td>September</td>
<td>813</td>
<td>55,093</td>
<td>1.5</td>
<td>Yes</td>
</tr>
<tr>
<td>October</td>
<td>-371</td>
<td>40,709</td>
<td>-0.9</td>
<td>Yes</td>
</tr>
<tr>
<td>1-Jul</td>
<td>-4,475</td>
<td>56,555</td>
<td>-7.9</td>
<td>No</td>
</tr>
<tr>
<td>3-Jul</td>
<td>1,909</td>
<td>51,781</td>
<td>3.7</td>
<td>No</td>
</tr>
<tr>
<td>21-Aug</td>
<td>2,450</td>
<td>63,654</td>
<td>3.8</td>
<td>No</td>
</tr>
<tr>
<td>28-Aug</td>
<td>1,825</td>
<td>54,750</td>
<td>3.3</td>
<td>Yes</td>
</tr>
<tr>
<td>30-Aug</td>
<td>2,346</td>
<td>61,341</td>
<td>3.8</td>
<td>Yes</td>
</tr>
<tr>
<td>4-Sep</td>
<td>-258</td>
<td>62,363</td>
<td>-0.4</td>
<td>Yes</td>
</tr>
<tr>
<td>6-Sep</td>
<td>524</td>
<td>56,540</td>
<td>0.9</td>
<td>Yes</td>
</tr>
<tr>
<td>13-Sep</td>
<td>1,303</td>
<td>48,811</td>
<td>2.7</td>
<td>No</td>
</tr>
<tr>
<td>23-Sep</td>
<td>-973</td>
<td>49,586</td>
<td>-2.0</td>
<td>No</td>
</tr>
<tr>
<td>30-Sep</td>
<td>3,470</td>
<td>58,165</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>4-Oct</td>
<td>1,548</td>
<td>31,660</td>
<td>4.9</td>
<td>Yes</td>
</tr>
<tr>
<td>17-Oct</td>
<td>511</td>
<td>47,495</td>
<td>1.1</td>
<td>No</td>
</tr>
</tbody>
</table>

*We used the 10/10 baseline for this analysis
OVERCOMING CHALLENGES: DEMAND RESPONSE AND PEAK LOAD REDUCTION (cont.)

Figure 4: Emission Reduction on DR days

Figure 5: CAISO Hourly Generation Mix for DR Days, Disaggregated by Fuel

Figure 6: CAISO Hourly Generation Mix for Baseline Days, Disaggregated by Fuel
OVERCOMING CHALLENGES: DEMAND RESPONSE AND PEAK LOAD REDUCTION (cont.)

Figure 7: Hourly GMEE -DR Days vs. Baseline Days - Average for All DR Events

Figure 8: GMEE Difference – DR Day vs. Baseline

Figure 9: Hourly GMEI Difference - Average DR Event Day vs. Baseline

Figure 10: Hourly GMEI - DR Day vs. Baseline Day
DISCUSSION
In this paper, we studied the load and environmental impact of DRPP participants. At the time this paper was written, we did not have all the data we needed to complete the study. However, preliminary load impact analysis showed that the DR performance of the sites varied significantly and there is a need to learn from best and worst performing buildings in the sample. Further work is needed to visit these sites and evaluate the lack of response observed in the initial data set. There is a need to commission DR control strategies to ensure they are working as intended.

For the environmental impact analysis part of this study, we discuss methods for linking ecosystem and human health benefits from demand response. We demonstrate a method for evaluating the emissions intensity associated with load and, by extension, the impacts of avoiding or shifting load to other times. For the SCE DR events that we analyzed, integrated 24-hour load was lower on DR event days than on their corresponding baseline days by an average of 1.1%. Emissions impact, however, varies based on the method used.

Because baseline days have a less emissions-intensive generation mix, DR days have higher emissions when using 1) the average DR day’s generation mix to calculate emissions impact on DR days and 2) the average baseline day’s generation mix to calculate a baseline day’s emissions impact. By contrast, if both DR and baseline days use the same generation mix – whether it’s a DR day’s mix or a baseline day’s – then the result is fewer emissions on DR days than on baseline days.

We caution readers to extrapolate our findings beyond the very short term, within-day construct for demonstrating the GMEI evaluation method. Clearly, over the long term, economic and environmental benefits associated with the potential roles of DR could be significant, but these benefits cannot be revealed within the timeline and scale of this study.

PERMANENT LOAD REDUCTION
In addition to DR, which is dynamic change in demand, permanently reducing peak electric loads in buildings is addressed differently within LEED depending if it is for new construction or existing buildings. In LEED for New Construction, EA Credit 1 is based on ASHRAE 90.1 and energy cost. Most energy storage systems, for instance cool thermal storage which makes and stores ice or chilled water at night to be used the following day to cool the building, are designed into buildings to take advantage of the difference between on and off peak electric rates. There is a large difference between energy costs during the day and night, on the order of 50%. So for new buildings, “credit” for peak load reduction in LEED comes by way of lowering energy costs and earning points in EA Credit 1.

Until the DR Pilot Credit and the Demand Response Credit in LEED v4, existing buildings had no way to get credit for permanent load reductions because EA Credit 1 is based on energy usage, not energy costs. The DR Credit for existing buildings now gives credit to building owners who recognized that reducing peak demand was cost-effective and beneficial to the grid and society and invested in permanent load shifting and peak shaving technologies accordingly.

There are LEED Gold projects that pre-date the new credit. For example, the Marriott Headquarters in Bethesda, MD, originally installed a cool storage system in 1992 to arbitrage the difference between day and night electric rates, and then changed the control sequence in 2007 to respond to DR signals from PJM. The change was made to take advantage of DR programs. To date, the system has received approximately $250,000 in DR credits with its participation in both voluntary and mandatory programs.

ACKNOWLEDGEMENTS
The authors would like to thank Southern California Edison, NV Energy, MelRok, and Enerliance for funding and participation in this effort. We would like to thank and acknowledge our contacts at each facility who participated in this study and provided valuable data and information.

REFERENCES
RESEARCH

E08:
FUTURE PROOFING BUILDINGS:
RESILIENCE IN THE AGE
OF CLIMATE CHANGE
ABSTRACT:
This summary paper provides an overview of opportunities for building owners and operators to understand 1) the risks associated with climate change and 2) some of the strategies for avoiding and/or mitigating those risks in new and existing building stock. Climate change will impact intensity and frequency of high temperature, precipitation, coastal erosion, air quality, pests and wildfires. The associated risks to building owners include cost to insure assets, cost to operate and impacts to business continuity. We reviewed a sampling of research to date and compiled resiliency strategies as applicable to new and existing buildings. We have focused our research on North America, but many of the strategies can be implemented outside of that geographic area.

Keywords: green building, built environment, resiliency, climate change, climate adaptation, adaptive capacity

INTRODUCTION
There are many resources available for building owners and operators to reduce or mitigate the environmental impact of their buildings, most often in the form of energy efficiency. This has been a proven strategy for addressing climate change because the business case is clear: saving energy is saving money. However, even if these efforts are successful, the effects of climate change are already underway and will continue for decades to come [1]. For this reason, increasing resiliency by ensuring buildings can withstand both extreme events and changing climate conditions is critical to increasing long term value and reducing exposure to risk.

While climate mitigation strategies are essential, the benefits are not always realized at the local scale. Reducing energy usage results in a correlated reduction in GHG emissions, but that does not necessarily translate to cooler ambient temperatures. Resiliency and adaptation strategies have more direct visibility and impact at the local scale because the strategies often target issues that are specific to a geographic location.

As defined by the Whole Building Design Guide, resiliency refers to “the capacity of a building to continue to function and operate under extreme conditions, such as (but not limited to) extreme temperatures, sea level rise, natural disasters, etc.” Adaptability is defined as “the capacity of a building to be used for multiple uses and in multiple ways over the life of the building.”[2] In relation to climate change, adaptability refers to the capacity for the building to adjust to changing climate conditions.

A clear business case is emerging for resiliency and adaptation as the concepts gain momentum in both the private and public sectors. In 2013, economic losses from catastrophic events worldwide were $140 billion.[3] 2013 also marked the year that for the first time in the US we spent more on disaster recovery than on national education.[4]

According to the Stern Review on the Economics of Climate Change, if left unmitigated the cost of climate change could increase to around 20% of global GDP by the end of the 21st century. [5] However, studies suggest that resiliency measures could avoid up to 68% of climate change risks. [6] According to a study conducted by the National Institute for Building Science for every dollar spent on disaster preparedness, four dollars are saved on future recovery costs.[7]

METHODOLOGY
In an effort to identify resiliency and adaptation strategies for buildings, we reviewed multiple reports, papers, and a few specific local efforts that called out strategies for improving resiliency in the built environment. Some of these efforts were focused on community-scale planning, but most were targeted to non-residential new construction and existing buildings. From this information—as well as the authors’ professional experience—we extracted and classified strategies applicable to new and existing non-residential buildings into seven primary physical categories: Energy Systems, Water Systems, Envelope, Equipment, Site/Landscaping, Materials, and Operations. Within this white paper we summarized strategies into five major categories.

CLIMATE CHANGE – WHAT ARE THE IMPACTS TO BUILDINGS?
In the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, “warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.”[8] In order to understand how to guide building owners and operators in how to respond, we must first understand the specific hazards and how they will impact buildings. New sources are needed for site specific design response by architects and engineers. Fortunately, sophisticated design tools have started to emerge, such as WeatherShift™, an energy modelling tool that allows design teams to better understand how a building will perform under future climate conditions [9].
Below we have summarized the climate change projections and how they specifically impact buildings:

<table>
<thead>
<tr>
<th>Climate Change Factor</th>
<th>Impact</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEA LEVEL RISE</strong></td>
<td>Decreased property value; Increased flooding of low-lying areas; Increased erosion; Increased storm surge; Increased cost to insure facilities in coastal areas</td>
<td>Sea levels rose by roughly 8” over the past century. Recent satellite data shows that in the last 15 years sea level rise has roughly doubled. Current projections show a range of sea level rise of 6’ to 10’ by 2100 [9].</td>
</tr>
<tr>
<td><strong>INCREASED TEMPERATURE</strong></td>
<td>Compromised thermal comfort and related health risks indoors and outdoors; Increased summertime cooling loads; Increased refrigerant tonnage necessary to achieve comfort levels; Increased operating cost for cooling; Exacerbated heat islands due to heat rejection; Compromised performance of air cooled equipment; Compromised performance of passively cooled buildings due to higher day and nighttime temperatures</td>
<td>By 2100, the average US temperature is projected to increase from 4°F to 11°F [10].</td>
</tr>
<tr>
<td><strong>CHANGE IN PRECIPITATION</strong></td>
<td>For areas prone to drought: Inadequate irrigation water supply; Less ability to rely on cooling system water; Potential water restrictions or rationing; Greater stress on electricity service and reliability effecting continuity of building operations For areas prone to flooding: Increased risk of water damage; overload of stormwater systems; higher flood insurance rates; Increased likelihood of water damage to facility</td>
<td>Northern areas are likely to become wetter, southern areas are likely to become drier. Precipitation is expected to fall as rain rather than snow. For each 1.8°F increase in tropical sea surface temperatures, the rainfall rates of hurricanes may increase by 6-18% and the wind speeds of the strongest hurricanes may increase by 1-8% [11].</td>
</tr>
<tr>
<td><strong>INCREASED WILDFIRES</strong></td>
<td>Increased wildfire damage in forests; Increased fire insurance rates; Increased cost to new development for fire service; Increased soil erosion following a fire affecting soil management</td>
<td>There has been a fourfold increase in large wildfires in recent decades, with greater frequency, longer durations, and longer seasons [12].</td>
</tr>
<tr>
<td><strong>DECREASED AIR QUALITY</strong></td>
<td>Decreased capacity for natural ventilation; Increased need for filtration; Increased incidence of health impacts; Occupant well-being compromised</td>
<td>Half of all Americans (158 million people) live in counties where air pollution exceeds national health standards. Higher temperatures make it more challenging to meet air quality standards, especially for ground-level ozone (a component of smog) [13].</td>
</tr>
<tr>
<td><strong>PESTS</strong></td>
<td>Increased risk of damage from insects to building materials and landscaping; Increased occupant exposure and concern related to insect borne disease and pest access to buildings</td>
<td>Rising temperatures allow insects and pathogens to expand their ranges, and allows more insects to survive winters [14].</td>
</tr>
</tbody>
</table>

Table 1: Summary of Climate Change Projections and Hazards to Buildings
FUTURE PROOFING BUILDINGS: RESILIENCE IN THE AGE OF CLIMATE CHANGE

CLIMATE CHANGE RISK CONSIDERATIONS
To help building owners understand how these hazards will impact their operations and asset value, we’ve identified the following top three risks:

COST TO INSURE
The reinsurance company Munich RE estimates that insurers faced losses of $510 billion from extreme weather events from the period of 1980 to present.[15] Given the current trends, insurers have started to require disclosures of climate risk in order to remain solvent.[16] With increased disclosure, insurers may find additional risk, and building owners will likely start to see increased premiums.

An example of this is the increase in insurance premiums that FEMA forecasted with the redrawing of the flood zones post Superstorm Sandy. In 2012, two senators put forward a bill, called the Biggert-Waters Act, which was aimed at reforming the National Flood Insurance Program (NFIP) administered by FEMA. The law “ordered FEMA to stop subsidizing flood insurance for second homes and businesses, and for properties that had been swamped multiple times.” Flood insurance rates are based on flood maps that were drawn in the 1960s, but after extreme storms like Sandy and Katrina the NFIP has a $24 billion debt. Flood maps were redrawn to better reflect the true flood risk of $527 billion of coastal property in the US, particularly areas that showed repeated instances. The result was a 10 fold increase in premiums. Currently the premium increases are put on hold with the Homeowner Flood Insurance Act, which President Obama signed in late March 2014.

COST TO OPERATE
In a 2006 report by the California Energy Commission, predictions show a 20.3% increase in annual electricity cost and a 10.3% increase in peak demand given worst case scenarios for GHG emissions. [18] This projection is based only on increase temperatures and their impact on cost of electricity. It does not take into account the other hazards and how they will impact operating and maintenance costs to a building.

For example, as ground level ozone increases, building owners and operators may start to see increased claims and decreased productivity due to effects such as sick building syndrome and asthma. It is estimated that sick building syndrome alone costs employers billions every year [19].

COST OF BUSINESS DISRUPTION
Depending on the building use and type of operations, climate change can have a significant impact on supply chain reliability and continuity. The 2013 Carbon Disclosure Project - S&P 500 Climate Change Report found that nearly 80% of the 5,000 respondents considered climate change to present business risk. Of those that consider climate change a risk, 63% said it was immediate (1 - 5 years) and 75% said the impact would be direct to their business operations. Risks to business continuity include damage to infrastructure, supply chain disruption, critical service interruption, or depletion of resources.[20]

RESILIENCY STRATEGIES
Based on the literature review conducted by the authors, the following major resiliency strategies can be applied across new and existing buildings. This is a partial summary. For a more complete listing of strategies by community type, the authors recommend Two Degrees: The Built Environment and Our Changing Climate [21]

Figure 3 – The Kirsch Center in Cupertino uses a mixed mode ventilation strategy, thermal mass, shading, and daylighting for improved passive survivability. Credit: Van der Ryn/ VBN

Increase Passive Survivability
Passive survivability refers to the ability of a building to operate during disruptive conditions such as extended power outages, fuel supply interruptions, and water shortages. Passive survivability covers a subset of strategies, including:

• Natural ventilation, daylighting and solar heat gain management to broaden the range of thermal comfort in occupied spaces
• High performance envelope to reduce need for conditioning indoor air
• Renewable energy source with battery storage to maintain building operations
• Onsite water collection for irrigation and sewage conveyance
• Food growing and storage areas incorporated into building and site design
BACK-UP CRITICAL SYSTEMS
One of the primary lessons learned from Superstorm Sandy is the importance of having back-up power supply for critical functions in a community. Lack of electricity after Superstorm Sandy was a bigger problem for many people than the storm itself, affecting 20% of New Yorkers.[22] In addition to conventional emergency life safety systems, priority systems can be backed up with any combination of:

- On-site renewable power generation (e.g. photovoltaics, wind, geothermal)
- Cogeneration, where waste heat from electricity generation is utilized to heat water or condition indoor air
- Electrical energy storage system

All backup power supplies should be located above flood level to ensure that backup systems can operate in the event of a flood.

DEVELOP EMERGENCY PREPAREDNESS PLAN
Building owners/operators should plan and organize with occupants to reduce potential harm of both peak climate events and changing climate conditions. Depending on the building type and usage, this may involve prioritizing actions based on vulnerabilities of certain occupants. Emergency Preparedness Plans should also be updated as more information becomes available about the intensity and frequency of climate events.

The first step in this process is to contact the local planning department to identify any existing tools and resources. FEMA also offers many resources for developing an emergency preparedness plan, all of which can be downloaded from the FEMA.gov website.

THINK BEYOND THE SINGLE BUILDING
Communities that have mechanisms for communication, collaboration and cooperation have better coping ability. Similarly, resiliency strategies are most successful when they are not implemented into just one building, but instead planned into the community. Examples of how communities/neighborhoods can use the built environment to support resiliency efforts include: creating areas of refuge and shelter, investing in resiliency priority zones (e.g. around hospitals), building in redundancy and service quality through community infrastructure (e.g. central cooling plants, community integrated renewable energy systems, centralized emergency generator systems).

CONCLUSION
Many existing buildings in North America are at risk due to climate change hazards in the near term. Adequate tools are needed for building owners and operators to assess risk and identify cost-effective resilience strategies that add value. This report serves as a step toward effectively sorting and communicating preventative actions for mitigating climate change impacts on new and existing buildings. Building owners/operators are advised to consider a building’s risk profile prior to making capital improvements and implementing resiliency strategies. In addition, local governments can support the effort by including climate risk assessments as part of the permitting process, and by providing tools for building owners to conduct climate risk assessments on existing facilities. As this effort evolves, more work is needed to document successful recovery efforts of buildings impacted by climate change.
REFERENCES


9. Environmental Building News; Tuning Today’s Building Designs to Tomorrow’s Climate; Melton, Paula; Roberts, Tristan; [Online] www2.buildinggreen.com/article/tuning-today-s-building-designs-tomorrow-s-climate


12. Ibid

13. Ibid


15. Ibid


20. McGregor, Alisdair; Roberts, Cole; Cousins, Fiona. (2012) Two Degrees: The Built Environment and Our Changing Climate; Taylor and Francis / Routledge; Ch15-20


RESEARCH

F08: THE INFLUENCE OF GREEN BUILDING EXPERIENCE ON THE USE OF HEALTHY BUILDING PRACTICES
THE INFLUENCE OF GREEN BUILDING EXPERIENCE ON THE USE OF HEALTHY BUILDING PRACTICES

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ABSTRACT:
Now that green building has achieved a strong foothold in the commercial construction sector, the attention of those engaged in green building is increasingly focused on the health impacts of their green projects compared to traditional buildings. A recent study conducted by McGraw Hill Construction demonstrates that experience with green building is a critical factor influencing the level of awareness of the health impacts associated with design and construction decisions on building projects, as well as the use of the healthy building products and practices. Among architects, experience with green has also increased the degree to which they see other factors besides owner demand as influential in driving industry engagement with healthy building products and practices. However, owners still do not prioritize health impacts compared to other desired outcomes like energy efficiency and improved aesthetics in their building design and construction decisions, even among those with a higher level of green experience. Increased public awareness of the impacts of building health is widely viewed as critical to encourage more industry engagement on this issue.

(Keywords: buildings, green, health)

INTRODUCTION
The 2014 National Green Building Adoption Index, jointly published by CBRE and Maastricht University, makes it clear that green building has firmly taken hold in the U.S. commercial construction market. The authors report that the amount of green certified commercial space went from 5.6% in 2005 to 39.3% in 2013, and they largely credit the implementation of energy efficiency programs resulting from a desire to reduce operating costs as a key driver for this growth. They state, “Overall, the results show that green-certified buildings now represent a major share of the U.S. commercial office market.”[1]

However, as the market grows increasingly green and many owners have seized the immediate savings offered by reducing energy and water use, additional market drivers may be needed to continue this momentum and increase the level and intensity of green building in U.S. commercial construction. One factor that can help drive renewed interest and investment in green building in the office sector is the ability to demonstrate the impact of green buildings on the overall occupant experience, including health and well-being. While annual utility costs typically average around $3.00 per square foot, and rents around $30, payroll costs routinely top $300 annually. If it can be demonstrated that the occupancy of a green building can measurably impact employee performance through a combination of factors including reductions in health care costs or sick days, enhanced employee recruitment and retention and actual productivity increases, tenants will actively seek these type buildings.

The challenge of attributing health cost reductions, employee behaviour, or productivity improvements to specific green building strategies, however, has prevented many owners from considering impacts on building occupant health and well-being in their calculation of the return on investment they gain from their green buildings, as opposed to more easily measured factors like reduced operational costs, increased building asset value, improved rents and improved occupancy.

Despite these challenges, greater attention to building health impacts and other factors have emerged in green building rating systems, and awareness and attention to improved indoor air quality, site design that encourages physical activity and other ways for buildings to impact health have generally been on the rise. In response to this increased attention to the impacts of buildings on occupant health and well-being, McGraw Hill Construction recently conducted a wide-ranging study that included many stakeholders who can potentially influence the incorporation of healthy building products and practices in projects, including architects, contractors and building owners from the non-residential building sector, medical professionals and human resource executives, residential architects and builders, and home owners. The findings are published in The Drive Toward Healthier Buildings: The Market Drivers and Impact of Building Design and Construction on Occupant Health, Well-Being and Productivity SmartMarket Report.[2]

One finding that emerged from that report is that green building has been an important driver for the awareness and prioritization of health impacts in the design and construction industries, as well as the use of healthy building products and practices. However, given the breadth of data gathered across the five studies, an in-depth examination of the differences in the responses of non-residential architects, contractors and owners based on their level of green involvement was not possible in the original publication. This paper provides a more detailed analysis of those responses in order to demonstrate how and to what degree green building has influenced wider interest in the impacts of buildings on the health and well-being of their occupants.

METHODS
Between March 28 and May 5, 2014, McGraw Hill Construction conducted an online survey of 733 professionals in the design and construction industry: 456 architects, 183 contractors and 94 building owners. The survey included questions on the influence of health impacts on building design and construction decisions, drivers and obstacles affecting the industry’s focus on the impact of buildings on health in the next two years, metrics used to gauge impacts, benefits measured and current and anticipated use of healthy building products and practices.

Respondents to the survey were also asked how they would characterize their company’s current level of activity in green building by the percentage of their overall projects. Those doing 15% or fewer green projects are classified in this analysis as having a low level of green involvement, those doing 16% to 60% as having a medium level of green involvement and those doing more than 60% green projects as having a high level of green involvement. A green building project was defined in the study as one that is built to LEED or another recognized green building standard, or one which is energy-efficient and water-efficient and addresses improved indoor air quality and/or material resource conservation.
RESULTS


For all respondents, regardless of the type of firm or their level of green involvement, a higher percentage expect that the impact of their building projects on the health of their occupants will have a high degree of influence on their design and construction decisions than the percentage who currently are highly influenced by the health impacts of buildings. However, the higher the level of green involvement for each player, the higher the percentage of respondents who report being influenced by health factors (see figure 1). In fact, 93% of architects with a high involvement with green expect that the health impacts of buildings will have a high/very high influence on their design decisions by 2016.

However, it is notable that there is a significant shift between 2014 and 2016 toward higher recognition of the importance of building health impacts, even among those with a low level of green involvement. While green involvement certainly influences the degree to which owners, architects and contractors are impacted in their design and construction decisions by health impacts, there is also a broader recognition of the importance of these factors emerging in the industry that is not solely tied to the level of green involvement.

Respondents were asked about the influence of health impacts as one of a series of factors that may influence design decisions. The other five factors they were asked about in terms of their influence on their design/construction decisions are energy savings, water savings, aesthetics, productivity and impact on the surrounding community. The high percentage of respondents that considered health impacts influential is not necessarily indicative of how building health impacts rank against those other influential factors. For example, even though 75% of architects with a high level of green involvement currently consider health impacts influential, health impacts actually rank fifth out of six when compared to the other factors. On the other hand, while the current percentage of contractors with a high level of green involvement who consider health impacts highly influential (63%) is much lower than the percentage of architects, health impacts do currently rank third for those contractors.

Despite these differences, by 2016, the second highest percentage of architects and contractors expect to consider health impacts highly influential, second only to energy savings (although health impacts do tie for second with water savings among contractors). Clearly, most architects and contractors believe health is becoming a much more influential factor overall.

Owners, on the other hand, appear to find other factors more influential than health and do not expect a major change. Health factors currently rank fourth in the percentage of owners who consider them highly influential, and they are only expected to inch up to third by 2016. Since owners are critical for setting the financial priorities on projects, advocates for healthier buildings need to concentrate on providing owners with better data about the benefits that healthier buildings offer.

METRICS FOR MEASURING BENEFITS

Over half of the owners (53%) use employee satisfaction and engagement to measure the impact of specific construction decisions on building occupant health. About one-third measure productivity (36%), workplace morale (32%), and well-being and quality of life (31%). 25% measure healthcare costs, and less than 20% measure absenteeism or rates of diseases related to air quality or lifestyle. 25% also report doing no measurements at all. Interestingly, there are no statistically significant differences among respondents doing more or less green work in terms of those who undertake measurements compared with those who do not. This is likely due to the fact that many owners are tracking these factors as a normal course of business, regardless of their building program.

Figure 1: Impact of Buildings on Occupant Health Has a High Influence on Firms' Design/Construction Decisions (Current and Expected Future by Level of Green Involvement).

Architects and contractors generally find that employee satisfaction and engagement are the most important factors to measure, followed by the rates of diseases related to air quality or lifestyle, and the measures considered most important are not influenced by their level of green involvement.
However, for architects in particular, the factors that they believe would encourage wider measurement are influenced by the amount of green work in which they engage. (See figure 2.) While a high percentage of all architects surveyed consider owner interest the top factor that would increase their commitment to measure building impacts on health, that percentage is much higher among architects who do little green work. In addition, a significantly higher percentage of architects doing more green projects find tools to be critical, such as standardized measurement tools and a national database.

These findings suggest that architects who have more experience with green are much more likely to consider having the right tools to conduct measurements influential, while more architects with less green experience feel that interest in measurement should come from the owner. Architects have long been at the forefront of championing green in the construction industry, so it is not surprising that those with a high degree of green experience may recognize that more data can be a powerful tool to encourage owner interest and investment in healthier buildings, as more data on the benefits of green buildings has encouraged owner investment in green building products and practices.

The same pattern is not evident in the contractor responses, suggesting that most contractors seek to take their cue from the owner in terms of measuring the health impacts from buildings.

**Figure 2: Top Factor Impacting Commitment to Measure Health Impacts in the Future (According to Architects)**

<table>
<thead>
<tr>
<th>Factor</th>
<th>1%–15% Green</th>
<th>16%–60% Green</th>
<th>More than 60% Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher Degree of Owner Interest in Health Issues</td>
<td>37%</td>
<td>38%</td>
<td>50%</td>
</tr>
<tr>
<td>Owner Willingness to Partner in Measurement</td>
<td>31%</td>
<td>35%</td>
<td>22%</td>
</tr>
<tr>
<td>Standardized Measurement Tools</td>
<td>9%</td>
<td>21%</td>
<td>11%</td>
</tr>
<tr>
<td>National Database to Provide Context of Results by Building Type</td>
<td>4%</td>
<td>8%</td>
<td>14%</td>
</tr>
</tbody>
</table>

**BENEFITS OF HEALTHY BUILDINGS THAT WOULD HAVE THE BIGGEST IMPACT ON BUILDING ROI ACCORDING TO OWNERS**

Because the specific benefits of healthy buildings were only asked of building owners who reported specifically measuring those impacts, the number of owners answering those questions was too small to evaluate in terms of level of green involvement. However, all owners were asked about which benefits of healthy buildings, if they could be achieved, would offer the highest return on investment (ROI) for their use of healthy building practices and products.

While most of the factors were relatively equivalent in their ratings by owners with higher or lower levels of green involvement, two factors had significant differences reported:

- 23% of owners with a high level of green engagement report that improved employee satisfaction is the benefit of healthy buildings that offers the highest ROI, compared with 13% of owners with a medium to low level of green engagement.
- 21% of owners with a high level of green engagement find that improved employee engagement is the benefit that offers the highest ROI, compared with 8% of owners with a medium to low level of engagement.

This finding may indicate the influence of the experience of green building on owners. Many owners have learned to place their faith on green building metrics that they can directly measure, such as reduced energy costs, to demonstrate the return on their green building investments. Surveys can determine how employee satisfaction and engagement are directly influenced by being in a healthy building, but it is much harder to distinguish the impacts of healthy buildings on measures like healthcare costs and improved productivity, which are broadly influenced by a range of factors and therefore can rarely be tied directly to specific building improvements.

This is important for two reasons. First, it demonstrates the importance of providing owners with data on how specific building practices and products influence factors like healthcare costs and productivity through controlled studies of these measures. Studies are now emerging to better make these connections, which will be important to help owners fully determine their potential returns on healthy building investments.

In addition, these findings demonstrate the factors that are currently likely to be the most influential to encourage owners to invest in healthy building practices, and in terms of evidence, they are potentially easier to gather. Architects, contractors and other building players seeking to influence owners may want to encourage more immediate investigation of these factors for their building projects.
USE OF HEALTHY BUILDING PRODUCTS AND PRACTICES

Across the board, a higher percentage of architects and contractors who are highly involved in green projects also use more healthy building products and practices. (See table 1). This demonstrates the importance of the widespread adoption of green building practices in helping to drive the creation of healthier building projects.

Table 1: Use of Healthy Products and Practices

<table>
<thead>
<tr>
<th>Products/Practices</th>
<th>Architects 1%–15% Green</th>
<th>Architects 16%–60% Green</th>
<th>Architects More than 60% Green</th>
<th>Contractors 1%–15% Green</th>
<th>Contractors 16%–60% Green</th>
<th>Contractors More than 60% Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low VOC Products</td>
<td>76%</td>
<td>90%</td>
<td>96%</td>
<td>68%</td>
<td>76%</td>
<td>90%</td>
</tr>
<tr>
<td>Non-Toxic Building Materials</td>
<td>67%</td>
<td>83%</td>
<td>94%</td>
<td>62%</td>
<td>84%</td>
<td>82%</td>
</tr>
<tr>
<td>Acoustic Comfort</td>
<td>58%</td>
<td>67%</td>
<td>82%</td>
<td>31%</td>
<td>44%</td>
<td>52%</td>
</tr>
<tr>
<td>Mechanical Ventilation Strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximizing Air Exchange</td>
<td>52%</td>
<td>66%</td>
<td>78%</td>
<td>56%</td>
<td>60%</td>
<td>79%</td>
</tr>
<tr>
<td>Spaces for Social Interaction</td>
<td>48%</td>
<td>60%</td>
<td>80%</td>
<td>23%</td>
<td>16%</td>
<td>37%</td>
</tr>
<tr>
<td>Design/Construction Strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encouraging Physical Activity</td>
<td>30%</td>
<td>41%</td>
<td>59%</td>
<td>13%</td>
<td>23%</td>
<td>37%</td>
</tr>
<tr>
<td>CO2 Sensors</td>
<td>34%</td>
<td>57%</td>
<td>75%</td>
<td>39%</td>
<td>46%</td>
<td>63%</td>
</tr>
<tr>
<td>Merv 8+ Filters or Higher</td>
<td>22%</td>
<td>45%</td>
<td>69%</td>
<td>37%</td>
<td>46%</td>
<td>66%</td>
</tr>
</tbody>
</table>

Interestingly, though, architects and contractors who are highly involved in green do not always see a higher level of value in many of these practices than do those with less green involvement. A higher percentage of architects and contractors with a high level of green involvement believe that the use of low VOC building products and non-toxic materials have a high impact on improving building occupant health than those with a lower level of green involvement. More highly green-involved contractors also report a high impact for Merv-8 filters than those less involved with green, but there is no equivalent difference among the architects by level of green. It is notable that use of these products can help earn LEED points as well.

However, mechanical strategies to increase air flow are recognized as having an impact on health by over 70% of architects and contractors, regardless of their level of green involvement, demonstrating that the industry as a whole recognizes the healthy impacts of increased air flow.

On the other hand, relatively few architects and contractors recognize acoustic comfort as having an impact on health compared to the other practices discussed above, and the number does not vary significantly between those with high or low green involvement. It is notable that currently, acoustic comfort is not associated with LEED points, again suggesting the influence of green building rating systems on encouraging awareness of healthy products and practices.

These findings demonstrate how interwoven the push for healthier buildings is with the push for greener buildings. They also suggest the ways in which the industry has learned the lessons of green building and is now applying them to this increasing aspiration for healthy buildings.

DRIVERS AND CHALLENGES FOR INCREASED ATTENTION TO HEALTH

The highest percentage of owners, architects and contractors find that greater public awareness of the health impacts of building design and construction is one of the top three drivers for encouraging the industry to focus more on healthy buildings. The more involved with green building the architects are, the higher the percentage who select this driver, from 39% of architects with low green involvement to 53% with greater involvement.

The findings of the overall study demonstrate a key challenge that needs to be addressed to encourage greater public awareness. Physicians, who have a strong influence on public perceptions in health-related matters, do not make the connection between buildings and health. In fact, only 32% of general practitioners, those with whom the majority of the general public interact, believe that buildings impact patient health.

The perception of challenges to increased attention to health in the industry by architects varied more by the level of green involvement than any other player, with each of the top five challenges identified by architects showing a statistically significant difference between those with a low and a high level of green involvement. As table 2 makes clear, architects with a high level of green involvement are more concerned about lack of public awareness and lack of data about the health impacts of specific design/construction strategies and building products, while those with a lower level of green involvement place greater weight on owner willingness to invest and the other factors builders must consider.

Contractors and owners with a high level of green involvement also are more concerned about the data on the health impact of products than those with lower green involvement, and greener contractors are more likely to select the lack of information on the health impact of construction strategies as one of the top three obstacles. These findings clearly suggest that firms with green experience recognize the value of having sufficient data to influence investment decisions.

Table 2: Top Challenge Preventing Companies From Making Health Impacts a Critical Factor in Their Design/Construction Decisions (Percentage Selecting Challenges as one of the Top Three)

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Architects 1%–15% Green</th>
<th>Architects 16%–60% Green</th>
<th>Architects More than 60% Green</th>
<th>Contractors 1%–15% Green</th>
<th>Contractors 16%–60% Green</th>
<th>Contractors More than 60% Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner Not Willing to Invest in Needed Improvements</td>
<td>70%</td>
<td>58%</td>
<td>49%</td>
<td>59%</td>
<td>52%</td>
<td>44%</td>
</tr>
<tr>
<td>Too Many Other Factors That Builder Must Consider</td>
<td>59%</td>
<td>52%</td>
<td>44%</td>
<td>30%</td>
<td>40%</td>
<td>44%</td>
</tr>
<tr>
<td>Lack of Public Awareness About Impact of Buildings on Health</td>
<td>34%</td>
<td>37%</td>
<td>54%</td>
<td>19%</td>
<td>34%</td>
<td>39%</td>
</tr>
<tr>
<td>Lack of Information on Health Impact of Specific Design/Construction Strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of Data on Health Impact of Specific Building Products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION

Experience with green building leads to greater awareness and concern about the impact that buildings have on health, as well as to a wider use of healthy building products and practices. In addition, architects with a high level of green involvement are also more likely to recognize the importance of sound metrics and tools for measuring the impact of buildings on health, in addition to the importance of engaging owners.

Owners are the most influential group in terms of influencing the use of healthy building products and practices, but even owners with a high level of green experience currently put more weight on more tangible green results, such as energy savings, and report that the benefits they would see as most important are also those that they believe they can measure.

The results demonstrate that more data is needed, as well as more education and communication with construction industry players and beyond, to help influence the market for healthier buildings.

REFERENCES

1. CBRE and Maastricht University. National Green Building Adoption Index 2014: p. 3-4.
RESEARCH

G08:
INDOOR ENVIRONMENTS AND HEALTH: FROM RESEARCH TO PRACTICE
INTRODUCTION

We have long known that building environments can affect health outcomes. Building standards and regulations address many of the risk factors associated with accidents, illness and disease transmission linked to building conditions. Yet there is much more to health than risk reduction. Reducing risks is a necessary, but insufficient, step toward intentionally creating health through building design and operations.

Many organizations and current initiatives are working toward this end. For instance, the U.S. General Services Administration and the Centers for Disease Control and Prevention are developing and pilot testing a health centered rating system for buildings that takes into account how to generate healthy outcomes through factors such as good ambient conditions, stair access, healthy food, and opportunity for exercise. Other examples include the U.S. Green Building Council’s LEED Design for Health Innovation Credit, the American Institute of Architects’ Design and Health Leadership Group, and New York City’s Active Design Guidelines.

Despite these new initiatives, there is much yet to learn about the pathways and mechanisms that connect health outcomes to the design and operation of buildings. We know little, for instance, about how building design, human behavior, interior design, and facility operations influence health in the aggregate or how these factors interact in real workspaces. Why does this matter? Without a good understanding of the mechanisms and pathways linking the features and attributes of the built environment to health outcomes, we risk making investments that have little impact. On the other hand, if health pathways are validated, the potential financial and productivity impact on employees and organizations will be substantial. The financial benefits include reduced costs of health care and medicine, improved overall functioning at work, and associated decreases in worker productivity (including noise, light, temperatures, and ventilation) are linked to job satisfaction, and associated decreases in worker productivity (Harter et al, 2002). Importantly, the physical conditions at work (including noise, light, temperatures, and ventilation) are linked to job satisfaction (Veitch et al, 2007) and are therefore implicated in the effects of work-related stress on health. However, there are no existing studies of physiological indicators of the stress response in actual work settings that link the health outcomes to the physical conditions in typical work settings. The research in the study reviewed below (Thayer et al, 2010) was intended to identify these potential linkages.

HYPOTHESIS TESTING

Testing hypotheses in real work settings is a critical step to understanding and validating the links between the built environment and positive health outcomes. The U.S. General Services Administration is currently testing the links between indoor environmental quality and health outcomes in four Federal buildings, one new building and three major renovations. A previous study of physiological stress outcomes in the Denver Federal Center serves as a “proof of concept” for the new research program. The Denver study, conducted by researchers from the National Institutes of Health, found that employees in a newly renovated space had lower physiological stress levels than a group of employees in an un-renovated space in the same building (Thayer et al, 2010).
Sixty employees participated in the study, with 13 participating for 24 hours and 47 for a second day. The study examined the effects of the physical work environment on two different measures of the physiological stress response, as well as on psychological measures of stress and mood. Repeated levels of the hormone cortisol were measured in saliva throughout the day to provide an indication of the status of the brain’s hormonal stress response. Continuous monitoring of heart rate and heart rhythms (heart rate variability) over a period of 24 hours using a wearable heart monitoring device, was used to detect changes in the neuronal component of the stress response at different times of day. Stress is associated with increased heart rate and decreased heart rate variability, both indicators of activation of the adrenergic (adrenalin-nerve mediated) component of the stress response. A decreased difference between nighttime and daytime heart rate variability is also an indicator of a stressed state. In contrast, high heart rate variability is healthy and indicates dominance of the vagus nerve in controlling and slowing the heart, and opposing stress. Each participant wore an ambulatory device for heart rate recordings and provided salivary cortisol samples five times a day. In addition, participants were asked to respond to an hourly prompt on a Palm Pilot asking them to rate the extent to which they felt stressed (from not at all to very much). The participants also reported on how much tobacco, coffee or alcohol they had consumed in the preceding hour.

HYPOTHESIS
The research tested the following hypothesis: improvements in the physical work environment, shown in other studies to be associated with job satisfaction, would be associated with increased diurnal heart rate variations and decreased morning rise in cortisol (both measures indicate lower levels of stress).

RESULTS
Results showed that the participants in the old, un-renovated workspace had higher levels of stress as indicated by lower vagally mediated heart rate variability, flattened diurnal difference in nighttime and daytime heart rate variability, and a greater morning rise in cortisol compared to participants in the newly renovated space. The effects were not mediated by health-related behaviors such as smoking, caffeine or alcohol consumption or physical fitness. The findings were also independent of any differences in perceived stress as measured by the psychological experience sampling using the Palm Pilot. Interestingly, there was no statistical difference in subjective psychological measures of stress. This could have been due to the relatively small numbers of subjects tested or could indicate that people are not subjectively aware of the degree to which the physical environment affects their stress responses.

DISCUSSION
The overall results of the research suggest that the physical work environment may influence at least some of the underlying physiological factors associated with the negative health effects of increased work stress. The fact that increased stress levels were found on two completely different measures of the stress response (cortisol and heart rate variability) is strong evidence for the impact of the physical environment on stress. The levels of increased stress detected are known in other studies to be associated with increased risk for stress related diseases in the long-term, such as cardiovascular disease, diabetes and stroke. Furthermore, these health effects occur without the individuals being consciously aware of a stressful experience. This finding has implications for research on stress in work settings. Many studies rely on subjective assessments which may not correlate with objective measures of health outcomes.

CONCLUSIONS
The study also showed that the physical environment, as a whole, may account for at least some of the stress effects of the work environment. This finding has important public health, social and economic implications for work environment risk factors on health. The study, however, did not address what specific features of the environment might account for the effects. Other research, however, suggests that noise, views to the outdoors, lighting, thermal conditions, and air quality may influence stress responses (Veitch et al, 2007, Ulrich, 1984, Walch et al, 2005). Understanding the links is critical for identifying specific design and building operations interventions that can be implemented to improve health outcomes in work settings.

STUDY 2. INDOOR LIGHT AND CIRCADIAN FUNCTIONING
Lighting design for office buildings has focused largely on the amount of light needed for work, strategies to reduce visual discomfort, and the use of daylight as a means to reduce energy in buildings. However, the lighting characteristics affecting the biological clock are different than those affecting the visual system. Little attention has been given to understanding how light affects occupants’ psychological and physiological systems, including circadian functions that regulate sleep, mood, and alertness. Daylight is an ideal light source for the circadian system, but it is not known whether those who work in spaces that have daylight are indeed receiving enough light to promote circadian entrainment while at work.

If health benefits are identified, this could have far-reaching effects on sustainable lighting design as not just a means to achieve energy efficiency goals but a means to enhance the health and wellbeing of federal workers, improve overall work effectiveness, and reduce long term health problems associated with circadian disruption (including sleep problems, mood disorders, and cardiovascular impacts). Furthermore, new technologies such as LED lighting could enable greater control over both the amount of light and its spectral characteristics, both of which are known to influence circadian processes and health outcomes in experimental settings.

The circadian light study is being conducted by a research team from Rensselaer Polytechnic University’s Lighting Research Center. The research has two main components: (1) an extensive photometric analyses of each of the study buildings in both winter and summer months and (2) analysis of the impacts of light exposure on the circadian system using a wearable device for seven days at work and at home. This paper describes the results on health outcomes linked to circadian functioning for one of the building sites, the Edith Green-Wendall Wyatt Federal Building in downtown Portland, OR. This 18-story building accommodates over 1200 workers from 16 federal agencies. Some areas of the building are accessible to the public. Originally built in 1974, EGWW was completely remodeled in 2013 to be extremely energy-efficient, earning LEED Platinum certification for its use of sustainable design and technology. The most distinctive exterior feature of EGWW is the ”reed” structure on the west facade of the building; the south and east facades employ other external shading devices. The north facade of EGWW is not shaded. As shown in the results below, these architectural features are likely influencing workers’ light/daylight exposures over the course of the day.
HYPOTHESIS
Indoor daylight, if it is of sufficient quantity and quality, can have health impacts mediated through the circadian system, including sleep quality and alertness.

METHODS
Photometric Analyses
Measurements were performed at two rows of desk on three floors with open-plan offices (floors 4, 12 and 17). The locations of the desk spaces were chosen to represent the four building orientations. Illuminance, luminance, and spectral power distribution measurements were taken at different times of the day. Reported here are the spectral power distribution (SPD) measurements. SPD is a measure of the wavelengths of light in the visible spectrum (380-770 nanometers (nm)). SPD will vary between light sources as well as time of day. SPD was measured at EGWW to allow researchers to calculate, using different response functions, measures such as brightness, glare, and circadian stimulus. SPD data were collected on the 4th, 12th and 17th floors at EGWW. A researcher collected these data at EGWW using a spectroradiometer system consisting of an Ocean Optics (model: USB650) spectrometer and a remote sensor, as well as a laptop. Raw SPD data were collected using the spectroradiometer system, and post-processed using Matlab version R2012a to generate curve functions.

PERSONAL WEARABLE DEVICE
Twenty-four participants working at the newly renovated building agreed to wear the Daysimeter (Figueiro et al. 2013), a calibrated light and activity meter, for seven consecutive days during the months of May and June 2014. The Daysimeters measure continuous light exposures, allowing researchers to perform calculations of how much light that is effective for the circadian system (i.e., circadian stimulus, or CS) the occupants of the building may be receiving (Rea et al. 2012). Participants wore the Daysimeter while awake (both in the office and at home) and during sleep. Using actigraphy data from the Daysimeter, it was possible to determine sleep parameters in this population. They also filled out a series of self-reports probing their sleep quality, depression and mood scores. The survey instruments included the Pittsburgh Sleep Quality Index (PSQI) (Buysee et al, 1999), the Karolinska Sleepiness Scale (KSS) (Akerstedt et al, 1990), the PROMIS Sleep Disturbance-Short Form 8a (Buysee et al, 2010), the Positive and Negative Affect Schedule (PANAS) (Watson et al 1988) and the Center for Epidemiologic Studies Depression (CES-D) (Radloff, 1977).

RESULTS:
Photometric Analyses
Table 1 shows average results during the daytime measurements (excluding evening measurements, since workers are not present after dark). (A desk location is near windows; B locations are farther away.)

<table>
<thead>
<tr>
<th>Deskspace Locations</th>
<th>Lux</th>
<th>Floor %</th>
<th>Day %</th>
<th>CCT(K)</th>
<th>CLa</th>
<th>CS</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>865</td>
<td>30%</td>
<td>70%</td>
<td>5321</td>
<td>1178</td>
<td>0.446</td>
<td>709</td>
</tr>
<tr>
<td>B</td>
<td>344</td>
<td>81%</td>
<td>19%</td>
<td>3632</td>
<td>344</td>
<td>0.288</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orientations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>675</td>
<td>59%</td>
<td>41%</td>
<td>4272</td>
<td>836</td>
<td>0.360</td>
<td>514</td>
</tr>
<tr>
<td>N</td>
<td>1001</td>
<td>40%</td>
<td>60%</td>
<td>5017</td>
<td>1375</td>
<td>0.490</td>
<td>812</td>
</tr>
<tr>
<td>S</td>
<td>302</td>
<td>65%</td>
<td>35%</td>
<td>4170</td>
<td>329</td>
<td>0.288</td>
<td>217</td>
</tr>
<tr>
<td>W</td>
<td>413</td>
<td>57%</td>
<td>43%</td>
<td>4396</td>
<td>462</td>
<td>0.324</td>
<td>313</td>
</tr>
<tr>
<td>Floors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>415</td>
<td>68%</td>
<td>32%</td>
<td>3968</td>
<td>439</td>
<td>0.328</td>
<td>292</td>
</tr>
<tr>
<td>12</td>
<td>487</td>
<td>63%</td>
<td>37%</td>
<td>4242</td>
<td>595</td>
<td>0.343</td>
<td>369</td>
</tr>
<tr>
<td>17</td>
<td>896</td>
<td>35%</td>
<td>65%</td>
<td>5175</td>
<td>1224</td>
<td>0.426</td>
<td>733</td>
</tr>
</tbody>
</table>

These data show the impact of window proximity on light exposure. At many of the A-desk measurements, CS values were above 0.3, which is considered the lower end of the threshold boundary for circadian stimulation. Most of the measurements at the B desk spaces on the south and west sides of the building had CS values below the desired amount. More importantly, the contributions of daylight were much higher in desk spaces close to the windows (row A) than in those far from the windows (row B). The table also demonstrates that workers on the north side of the building were exposed to higher light levels (and more contribution from daylight) than the other sides of the building. Consistent with our observations in other buildings, the use of shades to remove direct sunlight on the other facades reduces the amount of available daylight. The data also show that occupants of the 17th floor were exposed to higher light levels (and more daylight exposure) than lower floors. These data are, however, snapshots of what the exposures are over the course of the working day. Daysimeter measurements, discussed below, may be a better representation of the continuous light availability over the course of the working day.

PERSONAL WEARABLE DEVICES
LRC calculated the CS values between 8:00 a.m. and 5:00 p.m. and found that the mean CS was 0.26 (mean = 175 lux), while the mean CS values outside working hours was close to 0.18 (mean = 49 lux). CS values are a surrogate for how much light stimulus activates the circadian system; a CS value of 0.26 is representative of a circadian stimulus that would result in 26% melatonin suppression if similar light levels were experienced at night for 1 h, while. Values above 0.3-0.4 suggest a strong stimulation of the circadian system. All subjects sitting by the North facade were exposed to CS values above 0.3. Consistent with the photometric measurements, the lowest CS values were associated with desk spaces located away from windows and in the South and East facades, most likely because window shades were drawn to reduce sunlight. Two workers who worked on the sub-floor had the lowest CS values. In general, the sleep efficiency and duration was low and results from self-reports sleep were mixed, with one scale suggesting that over half of the subjects had sleep disturbances while another scale suggests that only 2 subjects had moderate sleep disturbances. Only two subjects reported feeling depressed and having negative mood. There were no strong correlations between CS values and subjective responses of sleep and mood, however.

DISCUSSION
The circadian stimulus experienced by those sitting on the North facade was satisfactory, but some who were sitting on the East and South facades were not receiving what we believe is a sufficient amount of circadian stimulation. This is an important observation, given that daylight was a major consideration in the renovation of the building. The facade on each orientation of the building was designed specifically to reduce glare and enable as much daylight as possible to reach the interior of the building. The use of architectural reeds turned out to be a successful technique on the West facade, especially on the higher floors and at desks located near the window. The architectural reeds reduced sunlight penetration and allowed daylight in the space because, unlike what is commonly found on west facades, the shades in this building were up and more daylight was available in that part of the building. However, in the East and South facades, occupant behavior and interior design decisions may be limiting the amount of daylight reaching occupants eyes. The shades were seen lowered more often and the seating arrangements were such that occupants were not facing the windows, and therefore, the amount of light at the eye were reduced. In fact, the photometric analysis showed that shades were frequently down even when conditions were appropriate for daylight. The office layout and furniture systems with high panels may also have reduced daylight penetration. However, this hypothesis needs to be further investigated.
It is also not known whether the circadian system will adapt to lower light levels and whether this stimulus, given that it was the strongest participants received during the day, would be sufficient to maintain entrainment to the 24 h solar day.

OVERALL DISCUSSION
Key findings from these two studies are as follows: (1) The indoor work environment can influence physiological functioning linked to stress outcomes and circadian processes. (2) Objective physiological measures in both studies did not align with subjective measures suggesting that people may not be consciously aware of how their bodies are responding to the environment. (3) Wearable measurement devices provide a breakthrough method to assess health outcomes and the links to specific environmental stimuli; and (4) The lighting study, in particular, provides evidence that the delivery of health benefits is not limited to window design features, but is also influenced by occupant behavior, interior design, and workstation features. Individual differences in environmental preferences may also play a role, although they were not a subject of inquiry in either study. For instance, people who experience Seasonal Affective Disorder (SAD) are described as “light seekers” and they prefer much high levels of light overall than people who do not experience SAD (Heerwagen, 1990). There is also evidence that some people are more sensitive to noise than others (Ellermeier and Zimmer, 1997). These factors may mediate links between health and the physical environment.

What have we learned from this research and what still remains to be discovered? First, it is clear from the circadian lighting study that awarding daylight credits for building rating systems should be based on occupant experience of daylight - not window design. The Edith Green-Wendell Wyatt building was carefully designed to provide indoor daylight while controlling glare from sun. As shown in the research summary, both the north and west orientations provided more circadian stimulation due to lower shade use. There was also variation due to desk location. The desk spaces situated away from the perimeter (and even some that were close to the perimeter) on the east and south sides were often not receiving enough daylight. As noted in the research summary and supported by other studies (Van Den Wymelenberg, 2012), occupants frequently close the blinds to reduce unwanted glare, but do not open them again when conditions improve. This action clearly reduces the potential for circadian functioning. Since EGWW did not have automatic shades, we do not know whether the circadian stimulus potential would have been better because the shades would be closed for only a portion of the day, not the entire working day. It is interesting to note, however, that the reed-like structure added to the west side of the building allowed for an increase in daylight availability at desk spaces near the perimeter because, unlike with other buildings, users did not have to pull the shades because the reeds reduced sunlight penetration while still allowing daylight into the space.

Another potential issue for daylight and health is the design of the interior space, including layouts, workstations, colors, electric light, and lighting controls. Because many projects separate interior design from building design, there is little consideration of how to integrate all of these factors from the beginning of a project. Personnel factors also complicate matters if window locations are used as part of the reward system in the organization. If daylight is a health benefit, then it should be available to all. Perhaps the most difficult interior decision of all focuses on the workstation itself, particularly panel heights. It is widely believed by employees that high workstation panels provide more acoustic privacy and reduce noise transmission. However, GSA research shows that satisfaction with privacy is not significantly better in workstations with high panels than workstations with low or no panels (GSA, 2002).

Results from the Denver workplace stress study reviewed here show that additional research is needed to identify the links between stress responses and specific environmental features. New more sensitive non-invasive wearable devices are now available to measure both a variety of health outcomes and environmental exposures.

GSA will be working with researchers, designers, engineers, building managers, human relations personnel, employee unions, and other key stakeholders to translate research findings into practical solutions and guidance. A key goal of this educational effort will be to dissolve the boundaries that currently make it difficult to design buildings and indoor environments that are good for people, the environment, the organizations housed in the building, and the bottom line of all participants.

REFERENCES
RESEARCH

H08:
REAL-TIME ENERGY MANAGEMENT:
YEAR 1 RESULTS & YEAR 2 PERSISTENCE
ABSTRACT:
Even the best commercial buildings have “operational stray” – sensors break, schedules are wrong for the season, and switches are set to manual. NRDC’s 2013 report on The Tower Companies’ Real-Time Energy Management project provided detail on how Tower worked with AtSite to identify and correct stray in three of Tower’s commercial office buildings, reduced the costs of the program while producing savings, determined other values for Tower, and established lessons learned for others exploring similar programs.

In this paper, we review certain key findings from the NRDC report and provide information from Tower and AtSite that offer a glimpse of the second year of the on-going program. Preliminary information (collected by Tower and AtSite) suggests the energy savings seen in the first year appear to persist through year two using similar methods as described in the NRDC Report. Based on Tower and AtSite reports of progress working with building teams, we provide an update to certain lessons learned, with an emphasis on engaging building staff.

INTRODUCTION
In December 2011, The Tower Companies (“Tower”), an owner and operator of commercial and multi-family residential apartment buildings, launched a program to optimize energy use in its buildings. The centerpiece of the program was to use energy usage information – electricity and gas meter data – to identify and correct system inefficiencies in the buildings and to take advantage of opportunities to reduce energy usage and costs. Tower engaged AtSite, a Washington, D.C. based sustainable solutions firm, to help implement the program and deliver energy advisory services.


The market for Real-Time Energy Management (“RTEM”) is growing, yet many building owners, utilities, tenants, and other market participants have questions about the effectiveness of programs and risk. While NRDC’s report found the Tower program delivered strong returns on the investment to implement the program, the results described were limited to the first year after implementation.

A key question for many market participants is whether a building owner or operator will maintain improved building performance after the initial period of savings. In this paper, the authors review NRDC’s findings and analysis of Tower’s RTEM activities. This paper then provides energy usage information (as reported by Tower and AtSite) in order to obtain directional insights into year two results.

TOWER’S REAL-TIME ENERGY MANAGEMENT PROGRAM
Tower’s RTEM program, as implemented in year one, is fully described in the NRDC report. The centerpiece of the program is the service delivered by AtSite. AtSite provides Tower with visibility into and intelligence around energy usage patterns to find anomalies and opportunities for improvement. To do this, Tower and AtSite identified data streams in each building to be monitored, including installing submeters on the chilled water units in each building and installing “pulse meters” to obtain the “whole-building” data (“whole-building” data is the same meter data that would be collected by the electric utility). AtSite’s cloud-technology platform, InSite, gives Tower customized data visualization, analytics, and reporting tools.

AtSite also delivers data analytics and engineering support to Tower. Key examples of this support include AtSite delivery and analysis of daily reports to Tower building teams illustrating previous day usage compared to its historical average. Tower building teams also maintained monthly in-person meetings with the AtSite efficiency experts throughout year two, including Tower executive management on a quarterly basis, to discuss progress, operational changes, and potential energy conservation measures (ECMs).

In addition, Tower cooperated with AtSite to perform seasonal walk-throughs of each building and periodic night audits, the purpose of which was to investigate issues identified in the data and recognize operations that needed to be corrected. Further, AtSite staff was in regular contact with Tower staff to diagnose energy usage anomalies identified in daily reports and resolve issues. At the outset of the RTEM program, Tower and AtSite focused on identifying and obtaining useful data streams, followed by using the data to identify trends, correlations, and predictions that would otherwise likely be hidden.
YEAR ONE RESULTS

NRDC found that during the first year of the program (2012), Tower realized a 13.2 percent reduction in electricity use and avoided nearly $220,000 in energy costs in the three commercial office buildings. Figure 1, also Table 1 from the referenced NRDC report, provides more detail regarding these energy savings.

Among the key lessons learned is that substantial gains are available to building owners that operate buildings with attention to low and no-cost energy efficiency strategies and consistent best practices. NRDC concluded the program would most likely deliver greater value for Tower than the energy savings reported and documented, such as reduced maintenance expenses, higher rents, and improved occupant/tenant comfort in the buildings. NRDC found that a range of measures implemented in the first year accounted for the savings.

YEAR TWO RESULTS

Major elements of Tower’s program and on-going activity as described in the NRDC Report remained in place for year two. Energy usage information for the three buildings (as recorded by AtSite and Tower) indicates that the savings realized in year one were maintained and substantial savings in each of the three commercial office buildings were achieved.

The 2013 data provided by AtSite illustrates that electricity usage was reduced by an additional 7% as compared to a normalized 2012, and 22% as compared to the 2011 normalized baseline. Figure 2 below describes electricity savings from the first and second years of the program.

CONTEXT OF FINDINGS

In this working paper, prepared to accompany an education session at the 2014 USGBC Greenbuild conference, the authors include preliminary results based on self-reported meter readings from Tower and AtSite without external review of the data and without an assessment of potentially material factors in the buildings that could have occurred in year two. The data presented in the NRDC report was derived from utility billing information, and the 2013 data presented here is collected by Tower’s installed meters. The results were adjusted for weather by AtSite (using a conventional method) as a baseline for comparison against 2012 usage. The 2013 results are also adjusted for occupancy, which was tracked and provided by Tower on a frequent basis.

NRDC has not separately validated the reported energy usage for 2013. The authors of the NRDC report participated in meetings with Tower and AtSite in 2012, observed ECMs, and reviewed energy usage data reported by the utility during the first year of the program. The contributions by NRDC in this paper were provided only in an effort to describe the conclusions from the original report, to provide directional results on persistence of savings based on the self-reported information, and to offer continued observations on lessons learned along with the members of the Tower and AtSite team.
RE-VISITING KEY LESSONS LEARNED

Operational stray will continue to occur, even in the best buildings. Several instances of operational stray from the first year of the program were detailed in the NRDC report, such as a chiller cycling on and off due to faulty sensors. With the RTEM program in place, Tower was able to catch and correct these instances quickly. Unlike making equipment repairs or replacement – catching and correcting system faults does not mean that new instances of stray will not occur and in fact, there are a few examples that show it continued to occur in year two of the program. These instances of stray indicate how maintaining RTEM programs beyond year one is likely to deliver continued value through more consistent operations. Without the RTEM program in place, it is reasonable to assume that Tower would have caught and corrected these anomalies many weeks or even months later than they in fact did, resulting in increased costs and resulting in wear and tear on equipment.

An example of stray is useful to consider. In 2013, an AtSite analyst noticed an unusual “bump” in night time usage in the building at 1828 L Street and contacted the building engineer. Refer to figure 3, which shows the “whole building” usage at the main electricity meter. A similar bump was not seen in the meter data tied to the building chiller plant, suggesting it must be coming from another source of errant usage.

ENGAGING BUILDING TEAMS & CULTURE CHANGE

One of Tower’s stated objectives at the outset of the program was to guide its building teams to make educated decisions based on granular energy usage information, made available from meters and submeters, in the day-to-day operation of its buildings.

NRDC documented in its Report the process of Tower building teams becoming comfortable with the help of AtSite’s analysts and engineers. NRDC highlighted the value of the AtSite team meeting with the Tower building teams to review findings and to track progress implementing corrective actions. These interactions appeared to help Tower to catch and correct anomalies quickly and served to help train the Tower facility teams on methods of using information to operate their buildings with greater control.

Even two years into the RTEM program (2013) these meetings continued to deliver value. Tower facility teams appeared to increase their ability to identify efficiency opportunities and take corrective action, which was reflected in increased ECM ideas more frequently being suggested by building teams. Tower believes it has succeeded in integrating new data sources and insights into day-to-day building operations.

Tower’s experience was that incorporating energy reduction as a priority was a slow process in many instances. For example, building engineers have many other competing tasks and day-to-day deadlines to assure building occupants are satisfied and their requirements are fulfilled. There are times when energy strategies and related actions items are not pursued as a priority. Follow-up by AtSite analysts and Tower managers remains a key ingredient in program success.

Implementing the program at scale has offered certain advantages, such as developing operational materials for Tower staff and buildings. AtSite developed customized guides and checklists (titled Standard Operating Procedures or SOPs) for the building teams. These 1-page documents for each building identify equipment-specific operating parameters tuned to outside conditions. The purpose of these documents is to serve as a reference guide when transitioning between seasons, when operators need to adjust certain operations as it relates to specific occupant requests and conditions. The documents are posted in each building’s engineering office as a quick reference guide for building operations.

NEXT DAY IS REAL TIME ENOUGH

NRDC’s report described daily reports AtSite sends by email to the Tower building teams reviewing the prior day’s usage, and in some cases the prior week’s usage. These reports are an important resource and a source of actionable intelligence about system usage in the building. The report data is energy-focused, and illustrates whole-building energy usage (not specific building components).

These reports appear to be sufficiently “real time” enough to deliver value to the user – in this case, building teams. By delivering usage results close to the time the usage occurred, building
teams are positioned to recall the events and tie any unusual usage to causes. Catching stray within a few days is likely to be a substantial improvement over the condition that appears common in commercial office buildings, which is to only notice and catch stray after it has persisted for an unknown period. This delay could be weeks, months, or more due to lack of more frequent data and only receiving utility invoices on a monthly basis.

VALUE-ADDS TO TOWER

In year one, Tower reduced energy expenses in an amount exceeding the hard costs to implement the program. The NRDC report explained that Tower likely realized substantial additional value from the program in the form of reduced maintenance expenses, higher rents, and more.

After year two, Tower realized several values from the RTEM program over and above the documented savings from lower electricity expenses. Examples of these additional benefits include:

• Reducing peak demand utility costs.
• Documented energy savings (substantiated by the AtSite system that enables the RTEM program) allowed Tower to participate in a custom incentive program called “CEIC,” which is operated by Pepco through the Empower Maryland program.
• Tower routinely surveys its tenants with regard to levels of satisfaction with the building; Tower is finding greater levels of tenant satisfaction in its surveys and has earned associated industry awards.
• Tower has benefited from substantially reduced water usage in the three office buildings, and management attributes this to better operation of the chilled water plants, which leads to reduced evaporation in the system cooling towers. While this has not yet been documented, it is consistent with findings and experience of other programs.

Tower implemented its RTEM program across a large portfolio of buildings. Tower owns and manages six (6) multi-tenant commercial office properties totaling approximately 1.3 million SF, and three (3) high-rise residential properties that total approximately 1.2 million SF (The Blairs). All are located in Washington, D.C. and nearby Montgomery County, Maryland, and all of these buildings are in the RTEM program.

The overall portfolio, which consists of commercial office and residential buildings, realized 11.6 % electricity savings or an estimated $485,000 in 2012 and 17.0% and $682,000 in 2013; both years are compared to a weather and occupancy normalized 2011 baseline.

CONCLUSION

Once a full cycle is complete, the focus should return to identifying the next set of high-value data streams to incorporate into the InSite platform. This is not a “one-size-fits-all” solution; some buildings may only need simple benchmarking, while other buildings may require full engineering support. The goal is to recognize the importance of continuity through visibility and access to a specialized support team.

Achieving substantial, consistent, and persistent energy savings in building operations occurs by approaching the process as a continuous and collaborative one. Tower and AtSite have implemented systems and processes that enable the building engineering and management teams to use information as a form of intelligence about building operations. This process establishes a continuous improvement program. The result is better, smarter, more sustainable buildings.

ACKNOWLEDGEMENTS

We very much appreciate the input and contributions of Philip Henderson (NRDC) who helped us to consider the key lessons learned and the need in the market for affirmation of savings persistence.

We would also like to recognize efforts by The Tower Companies’ former Chief Sustainability Officer, David Borchardt, who played a key role and helped to take the program from initial concept and development through implementation and beyond to yield significant savings. Jim Lewis, VP of Engineering for The Tower Companies, was instrumental from the beginning and continues to support and lead the building engineering teams to achieve great success. There are also many contractors associated with the success of this program including, but not limited to, HVAC Concepts, LLC and CDS Mechanical.

Justin Lee, Sam Quinn, Brandon Chase, Erin Beddingfield, and many other team members were the engineering and analytical brains behind the AtSite team for the initial two years of the program. Their knowledge and attention to detail provided great momentum for years to come.

Of course, this real-time energy management program would not be possible without the constant cooperation, enthusiasm, and collaboration from The Tower Companies’ passionate and energetic building engineering and property management teams. These teams include, but are not limited to, Marvin Atwell, Dave Chalmers, Dennis Gage, Nancy Hamaty, Eric Harris, Mike Newman, Donna Nurmi, Nathan Sims, Kendrick Smith, and Debbie Webb.

In closing, we would especially like to thank Jeffrey, Gary, and Ronald Abramson, Partners of The Tower Companies, for their pioneering leadership and support throughout the entire program. They are recognized throughout the industry for sustainability leadership and this program is only one representation of how they lead by example.

RESOURCES

3 We note that Tower implemented the real-time energy management program in many buildings in its portfolio, including 2.5 million square feet of owned and managed commercial and high-rise residential buildings. NRDC’s report examined only the results of the program in three multi-tenant commercial office buildings in downtown Washington, D.C.