3.0 The Social Benefits of Sustainable Design

The social benefits of sustainable design are related to improvements in the quality of life, health, and well-being. These benefits can be realized at different levels – buildings, the community, and society in general. At a building level, research on the human benefits of sustainable design has centered on three primary topics: health, comfort, and satisfaction. Although these outcomes are clearly interrelated, they have different scholarly roots and employ different methodologies. Health issues are the domain of epidemiologists and public health professionals. Comfort is studied by researchers with expertise in building science and physiology, while well-being and psychosocial processes are studied by environmental and experimental psychologists. The research described in this section integrates findings from these diverse areas, with a focus on studies that assess the health, comfort, and well being outcomes associated with the presence or absence of sustainable building components.

The building environment can have both negative and positive impacts on the occupants' quality of life. Negative impacts include illness, absenteeism, fatigue, discomfort, stress, and distractions resulting from poor indoor air quality, thermal conditioning, lighting, and specific aspects of interior space design (e.g., materials selections, furnishings, and personnel densities). Reducing these problems through sustainable design often improves health and performance. Improved indoor air quality and increased personal control of temperatures and ventilation have strong positive effects. In addition to reducing risks and discomforts, buildings should also contain features and attributes that create positive psychological and social experiences. Although less research has been done on health-promoting environments, emerging evidence shows that certain sustainable building features, including increased personal control over indoor environmental conditions, access to daylight and views, and connection to nature, are likely to generate positive states of well- being and health.

Another emerging social issue affecting buildings is security. Since September 11, 2001, Federal agencies have experienced heightened concern about how a building's features affect its ability to thwart or withstand hostile actions. The relationships between sustainable design and building security are important topics that will be discussed in this section.

At a community or societal level, the social benefits of sustainable design include knowledge transfer, improved environmental quality, neighborhood restoration, and reduced health risks from pollutants associated with building energy use. Although more research has been conducted on the benefits of sustainable design features to building occupants, interest is growing in the community benefits of sustainable design, and several potential areas of value to the Federal government are discussed at the end of this section.

The first two sections below describe research results indicating positive impacts of sustainable buildings on occupant health (Section 3.1) and comfort, satisfaction, and well-being (Section 3.2). (Appendix F discusses these topics in more detail.) Section 3.3 describes the potential benefits of energy efficiency and other sustainable design features to occupant safety and security. Section 3.4 describes potential positive community impacts.

3.1 Better Health of Building Occupants

Studies of the health benefits of sustainable design focus primarily on indoor environmental quality, especially air quality. Health effects result from environmental stimuli interacting with the body's physical systems, especially respiratory, skin, neural, and visual pathways. Illness symptoms occur because environmental agents (such as chemicals or airborne microbials) affect the operation of the body's physical systems in vulnerable persons.

Many studies have found high levels of air-quality problems and occupant illnesses in office buildings (e.g., Brightman and Moss 2001). Studies have begun to assess the causal relationships between the building environment and illness symptoms in three areas: (1) sick building syndrome (SBS), (2) asthma and allergies, and (3) communicable and respiratory diseases (Fisk 2001). Research Summary 3-1 shows an example of such a study. The findings of this research show that the three types of illnesses are affected by different components of the environment:

- **Sick building syndrome.** SBS symptoms include headache; fatigue; dizziness; irritations of the skin, eyes, and nose; and difficulty breathing. A large review study of the links between health, perceived air quality, absenteeism, and ventilation found that ventilation rates lower than 10 L/s per person were associated with statistically significant worsening of symptoms in a range of building types.[44] Increases in ventilation rate above 10 L/s up to 20 L/s per person were associated with decreased symptoms and improvements in perceived air quality. A ventilation increase of 5 L/s per person could reduce the proportion of workers with these respiratory symptoms from 26% to 16% and those with eye irritations from 22% to 14% (Seppanen et al. 1999). SBS symptoms are also reduced by personal control over thermal conditions (Preller et al. 1990; Hedge et al. 1993), improvements in ventilation system maintenance and cleaning, reduced use of pesticides, and daily vacuuming (Sieber et al. 1996).
- **Allergy and asthma symptoms.** Several building factors – moisture problems, molds, and dust mites – are strongly associated with asthma and allergy symptoms (Fisk 2002). Reducing the concentrations of allergens and irritants reduces symptoms. Successful strategies for reducing such concentrations include improving HVAC maintenance and cleaning and using building practices that reduce moisture buildup (Sieber et al. 1996). Other strategies include air filtration, humidity control, and elimination of indoor smoking. Asthma symptoms were found to more likely occur in the presence of new drywall and in building interiors with cloth partitions (Sieber et al. 1996).
- **Transmission of infectious diseases.** Infectious diseases can be transmitted by airborne microbes (viruses, bacteria). Airborne transmissions can be reduced significantly through ultraviolet irradiation of air near the ceiling, improved ventilation, and reduced crowding (Fisk 2000b; Seppanen et al. 1999). One study found that workers with one or more officemates were 20% more likely to have two colds during the year than workers who did not share an office (Jakkola and Heinonen 1993). Studies showing reduced risk with lower crowding do not identify what level of density is desirable for health reasons.

Health problems can be linked to absenteeism. A study of absenteeism among office workers in a large East Coast company found that the absenteeism rate was 35% lower in offices with higher

---

[44] Ventilation and air circulation are important, but sometimes overlooked, features of sustainable buildings. Ventilation refers to the air exchange between the outside and the inside of the building. Circulation refers to the air movement within and between the interior spaces of the building. Both ventilation and circulation can be achieved through mechanical means (e.g., fans within air ducts) or by utilizing natural principles (e.g., warm air naturally rises). In either case, a well-designed system should provide sufficient ventilation to dilute contaminants generated within the building space (by either building components or occupants) as well as adequate air circulation within and between building spaces to disperse built-up air contaminants locally while not adversely affecting the occupants' perception of temperature (e.g., creating drafts). It is particularly important that measures to increase energy efficiency by "tightening up" a building take into consideration the need to maintain adequate ventilation rates. Good ventilation and energy efficiency can be achieved simultaneously by using sustainable building measures such as heat recovery devices.

ventilation rates (about 24 L/s per person) compared with moderate rates of 12 L/s ((Milton et al. 2000). The use of humidification and complaints about air quality were also associated with increased sick leave. The study analyzed sick leave of 3720 hourly workers in 40 buildings. The study controlled for gender, age, seniority, hours of nonillness absence, shift, ethnicity, crowding, and type of job. (See Section 2.6 for additional information about absenteeism.)

Research Summary 3-1: Improved Ventilation Rates and Lower CO_2 Concentrations Reduce Illness Symptoms in Office Workers

Researchers conducted a critical review and synthesis of research on the associations between ventilation rates and occupant health to provide a scientific basis for setting health-related ventilation standards. The review shows that illness symptoms are often associated with low ventilation rates, high CO_2 concentrations, and perceptions of poor air quality.

Research Team: The research team included O.A. Seppanen from Helsinki University of Technology, W.J. Fisk from Lawrence Berkeley National Laboratory, and M.J. Mendell from the National Institute for Occupational Safety and Health.

Methodology: Both cross-sectional and experimental studies were reviewed. The following criteria were used for including cross-sectional studies:

- The study included at least three buildings or ventilation zones.
- Results were statistically analyzed and included controls for other factors that can influence health outcomes.

The following criteria were used for including experimental studies:

- No changes occurred in the air-handling system, and occupants did not move to a different building.
- A control group or multiple applications of experimental conditions were used.
- The subjects were not aware of the timing of changes in the ventilation rates.
- Results were statistically analyzed.

These criteria resulted in the selection of 20 studies with 30,000 subjects for investigating the association between ventilation rates and human responses, and 21 studies with over 30,000 subjects for investigating the relationship between CO_2 concentrations and human responses.

Key Findings: Some of the key results of the review are as follows:

- All studies assessing respiratory illness found a significant increase in the risk of illness with lower ventilation rates.
- Of the 27 studies dealing with SBS, 20 found a significantly higher prevalence of at least one symptom with lower ventilation rates.
- Findings of illness symptoms were especially consistent with ventilation rates of less than 10 L/s per person.
- Lower ventilation is also associated with increased perceptions of poor air quality.
- CO_2 studies supported the ventilation findings; in half of the studies, symptoms improved significantly when CO_2 concentrations were below 800 parts per million (ppm).
- Studies did not find a definitive ventilation rate that prevented symptoms.
- Only 5 of the studies were conducted in hot humid climates. Results may therefore apply primarily to moderate and cool climates.

Source: Seppanen et al. (1999).

3.2 Improved Comfort, Satisfaction, and Well-Being of Building Occupants

Psychological effects (e.g., comfort, satisfaction and well-being) are generated through perceptual and sensory processes that interpret environmental information in terms of its effect on current needs, activities, and preferences. The psychological "interpretation" of the environment has consequences for work performance and productivity (as discussed in Section 2.6), stress, and well-being. Because of the inherent variability in psychological responses, the same environmental conditions can affect different people in different ways as well as affect the same person differently over time, depending on the context.

Occupant comfort and satisfaction with building conditions are a primary focus of post-occupancy evaluations. The research generally shows that occupants' satisfaction with lighting and air quality is higher than their thermal and acoustic satisfaction (Leaman and Bordass 2001). Efforts to improve comfort and satisfaction are important because discomfort has negative consequences for work effectiveness, job satisfaction, and quality of work life.

A number of studies indicate that certain building features such as daylight, views, connection to nature, and spaces for social interaction, appear to have positive psychological and social benefits. The benefits include reduced stress, improved emotional functioning, increased communication, and an improved sense of belonging.

Occupants' satisfaction with several building features has been examined in a number of studies described below:

- **Satisfaction with daylighting and electric lighting.** A study of seven energy-efficient buildings in the Pacific Northwest found that 70% of the occupants were satisfied with lighting overall (Heerwagen et al. 1991). Factors that most influenced lighting satisfaction were access to windows and daylight, some degree of control over lighting, and the occupant's location in the building (those on the east and in corner spaces were most satisfied). Workers in windowed areas were 25% to 30% more satisfied with lighting and with the indoor environment overall, compared with workers having reduced access to windows. The Pacific Northwest study found that occupants valued daylight for its variability both across the day and across seasons (Heerwagen et al. 1991). Several reviews have also found that satisfaction with electric lighting improves with reduced glare problems and with increased brightness of vertical surfaces, including walls and cubicle partitions (Collins et al. 1990; Collins 1993).

- **Thermal satisfaction.** Thermal satisfaction is consistently lower than lighting satisfaction in most building studies partly because of the high variability in thermal comfort. Occupant responses to the thermal environment are influenced by activity, clothing levels, stress, age, gender, and individual preferences. The most effective way to improve thermal comfort and satisfaction is by using individual controls for temperature and ventilation (Wyon 1996). The responsiveness of building management to complaints also improves comfort and satisfaction (Leaman and Bordass 2001).

- **Perceptions of air quality.** Negative perceptions of air quality are common and are associated with low ventilation rates (Seppanen et al. 1999). In six cited studies, 50% of occupants said the air quality in their buildings was unacceptable, even though the building itself was not considered a "complaint" building (Seppanen et al. 1999). Increased ventilation improves perceptions of air quality if the intake air itself is located at least 25 feet from an irritant source (e.g., an exhaust vent, traffic, or a trash dumpster) (Sieber et al. 1996). Air quality is also associated with food and its odor problems, especially when the food is eaten by workers at their desks (Heerwagen et al. 1991).

- **Overall satisfaction.** A recent, large-scale study (Leeman and Bordass 2001) of 16 buildings in England identified several features that were consistently associated with higher levels of overall satisfaction:
  - Shallower plan forms and depths of space (buildings and rooms that are long and narrow)
  - Thermal mass
  - Stable and comfortable temperature conditions
  - Operable windows
  - Views out
  - Usable controls and interfaces
  - Places to go at break time
  - A well-informed and responsive building management.

- **Psychosocial well-being.** Although sunlight can create glare and heat gain in buildings if it is not controlled properly, evidence suggests that a modest level of sunlight indoors ("sun spots") significantly enhances psychological functioning and job satisfaction compared with spaces lacking daylight and sun (Leather et al. 1998). Although people prefer being in windowed rather than windowless spaces, the view itself has consequences for well-being. Studies have found that views of nature are especially beneficial and reduce stress, provide mental relief, improve perceived quality of life, and improve emotional functioning (Ulrich 1984; Clearwater and Coss 1990). A case study (Heerwagen 2000) of the Herman Miller building in Holland, Michigan, shows improvements in social functioning and sense of belonging associated with including break areas; a centrally located cafeteria; an interior, daylit and tree-lined "street"; and high levels of internal glazing that offered views into the street and interior spaces (see Research Summary 3-2).

3.3 Occupant Safety and Security

In the wake of the September 2001 attacks, every Federal agency faces a heightened concern for providing safe and secure workplaces and public spaces in Federal office buildings, military facilities, and other public facilities. At first, it might seem that features aimed at improving security will inevitably require some sacrifice of energy efficiency or other sustainable design characteristics. For example, sustainability principles might be considered inconsistent with using additional steel and concrete to increase blast resistance, eliminating natural ventilation, reducing window areas (daylight, passive solar heating) to minimize danger from flying glass, and increasing energy use from ventilation fans associated with high-performance air filters.

> *"In the process of renovating the Pentagon, we've found that several of the force protection measures we are taking to protect the Pentagon against terrorist attacks are complementary to our sustainable construction efforts. These are all examples of building security and energy efficiency working hand in hand."*
>
> Teresa Pohlman, Special Assistant for Sustainable Construction, U.S. Department of Defense

While such tradeoffs may be required in specific cases, a careful examination of the options for integrated design, at both the individual building level and at the site (or "campus") as a whole, has led many designers to conclude that improved building security and improved energy efficiency/sustainability not only can coexist but can even be complementary.

Research Summary 3-2: Herman Miller Improves Worker Satisfaction and Productivity

This study examined occupant satisfaction, as well as productivity (based on Herman Miller's own TQM metrics). Results indicate that the new sustainable building had positive impacts on occupants' well-being, job satisfaction, feelings of belonging, and other aspects of work life that affect individual job performance. The study also found that a small increase in organizational productivity occurred after the move to the new building.

Research Team: PNNL, J. Heerwagen, lead.

Research Setting: The Green House, designed by William McDonough and Partners of Charlottesville, Virginia, is a 290,000-ft^2 building that combines a manufacturing plant and office facilities/showroom for Herman Miller, Inc., a furniture manufacturing company. This facility is located in Holland, Michigan. The building has the following sustainable features:

- Extensive daylighting, including an interior daylit "street," windows, skylights, and roof monitors in the manufacturing plant
- Operable windows in both the manufacturing plant and office
- Views to the surrounding countryside from all locations
- Energy-efficient glazing and lighting
- Lighting controls that dim electric lighting when daylight is sufficient
- Occupancy sensors
- Increased filtration of particulates and increased air changes/hour in the manufacturing plant
- Nontoxic adhesives and a separately ventilated painting area in the manufacturing plant
- Restored prairie landscape and wetland on the site
- Extensive recycling of waste from the cafeteria, office, and manufacturing plant
- Siting to reduce the visual impact of the building from the road
- In-house fitness center.

Methodology: A research team from PNNL conducted a pre- and post-occupancy study that included occupant surveys and analysis of organizational TQM data. The data included overall productivity, on-time delivery, product quality, and efficient use of materials. DOE's Office of Building, Technology, State and Community Programs funded the study.

Key Findings: After moving into the new facility, the occupants experienced the following:

- Increased sense of well-being, belonging, and work spirit
- Increased job satisfaction
- Increased feeling of looking forward to work and being in good spirits at work
- Higher satisfaction overall with the building, especially the daylight, windows, electric lighting, air quality, and connection to nature.

The responses of the manufacturing workers varied across the shifts, with the daytime workers responding most positively. The night workers showed little difference between the buildings, possibly because the environment changed the least for them (daylight, views, and connection to the outdoors are greatly diminished at night).

Analysis of the pre- and post-occupancy results related to Herman Miller's TQM led to the following conclusions:

- A small increase of 0.22% occurred in overall productivity and small increases of 1% to 2% occurred in other TQM metrics. These increases were small but are still significant because the organization was already performing at 98% to 99% on all of the TQM metrics.
- No dip in productivity occurred following the move to the new facility. Most moves or major changes are followed by a period of slowdown, but this did not occur.
- No differences occurred in any of the TQM metrics across the manufacturing shifts, despite the differences in perceptions and subjective outcomes. This result suggests that the link between performance and subjective experiences is more complicated than is currently believed.

Source: Heerwagen (2000).

Examples of the synergy between building security and sustainability features can be seen from the Pentagon renovation project.[45] A spray-on wall coating selected to improve blast-resistance also helps improve the air tightness of the building envelope. The tighter envelope not only saves heating and cooling energy but also provides added protection against outside releases of airborne chemical or biological agents. The U.S. Department of Defense reports that new blast-resistant windows chosen to replace the original ones at the Pentagon are also 50% more energy efficient. Another feature is the choice of photo-luminescent signage to mark evacuation routes; these require no standby power and are also easier to see through smoke caused by a fire or explosion than conventional exit signs. A final example from the Pentagon project is the use of zoned climate control systems that not only reduce heating and cooling energy use and improve indoor air quality but also make it easier to control smoke and manage the spread of chemical or biological toxins in response to an emergency.

The U.S. Department of State is actively researching innovative structural and glazing systems that provide both daylight/view and – because they are designed to yield to an external blast – better protection for building occupants. Planners responsible for overseas Embassy compounds also maintain that the greater setbacks required for new buildings also provide important opportunities for sustainable landscaping, solar access, and other highly desirable features as a valuable by-product of security requirements.

The National Aeronautics and Space Administration incorporated both building security guidelines and sustainable design in their criteria for new facilities. They have found that certain standard design criteria, such as structural requirements for wind and seismic loads, can also help improve blast-resistance.

Ideally, projects targeted at improving building security should also consider opportunities to "piggyback" energy-efficiency and renewable energy measures because the energy cost savings could make security improvements more affordable. A few other examples of positive interactions between security and efficiency measures in buildings include the following (Harris et al. 2002):

[45] Personal communication with T. Pohlman, U.S. Department of Defense, Washington, D.C.

- Improving control of air distribution systems – including periodic calibration of sensors, adjustment of dampers, and other system maintenance – is essential for rapid response to an emergency and also contributes to energy-efficient operation under normal conditions.
- Tighter building envelopes have the dual benefits of reducing energy losses from air infiltration and making it easier to pressurize a building and therefore reducing entry of airborne hazards released outside the building.
- Daylit spaces may be easier to evacuate quickly in the event of an attack or threat accompanied by a power outage.
- Onsite power systems can be very attractive considering their improved reliability during utility system outages (either natural or human-caused), in addition to any cost savings that might be associated with reduced electricity or peak power demand.
- Upgrading existing windows for blast resistance may create opportunities to improve thermal and optical (daylighting) performance, if the window system or add-on film is selected carefully. For example, in planning for a recent retrofit project, DOE evaluated several blast-resistant films with varying thermal and optical properties and then pilot-tested the samples on windows in several offices.
- Redesigning security lighting along with automated sensing and surveillance systems may actually reduce the need for constant high nighttime lighting levels, while improving detection capabilities.
- Improving particle air filtration has several potential benefits. In addition to protecting buildings from biological agent attack, the benefits include reducing indoor particle concentrations from other sources, thereby improving occupant health (and productivity), and helping reduce HVAC coil fouling, which in turn improves heat exchange efficiency. Some high-performance filters have significantly lower pressure drop than others that do the same job, so a careful choice of filter systems and products can produce cleaner and safer air with less energy penalty.
- Site planning that provides a wide buffer zone to keep vehicles away from the exterior of a public building can also provide opportunities for better solar access and for climate-appropriate landscaping. Trees can directly shade the building and both channel prevailing summer breezes toward the building and temper the effect of cold winter winds on space heating loads. In addition, trees and other vegetation cool the building site due to evaporation that occurs during the plants' normal biological processes (evaporation causes cooling).

More examples can be found in Research Summary 3-3 at the end of Section 3.

3.4 Community and Societal Benefits

The effects of sustainable building practices on occupants are the primary social benefits that have been researched; however, various secondary and indirect quality-of-life benefits, for which anecdotal evidence exists, can accrue to other societal groups.

From a public health perspective, quality of life can be measured in terms of individual life expectancy and state of wellness. More generally, quality of life at a community level can include such issues as environmental quality, aesthetics, educational and recreational opportunities, accessibility and quality of public services, and even psychological characteristics such as community satisfaction and pride.

Sustainable building practices can contribute to quality of life in a number of ways:

- Occupants who experience increased job satisfaction, health, and productivity will carry these experiences back to their families and friends in the community, thus influencing overall well-being.
- Occupants may also enjoy more pleasant and productive commutes to work and less traffic congestion in their communities if public or alternative transportation methods are made available at their workplace.
- Benefits can potentially diffuse beyond the workplace and lead to increased use of sustainable design practices and behavioral change in the community at large. Behavioral changes might include increased recycling, purchasing green products, and investing in energy-efficient technologies.
- Buildings that include sustainable features also become models for others to follow. For example, the Herman Miller Green House regularly provides tours and outreach programs for local and national design and construction professionals as well as for businesses that are planning their own sustainable buildings.
- Environmentally conscious construction practices will tend to generate lower amounts of dust, pollution, noise, traffic congestion, and other community disturbances. These improvements will likely contribute to improved public health, safety, and well-being. (The environmental benefits of sustainable buildings are discussed in greater detail in Section 4.)
- Construction practices and building operation practices that foster recycling and reduce waste generation, energy use, and water consumption will eventually reduce the demand for new landfills, electric utility plants, transmission and gas pipelines, and wastewater treatment facilities (see Section 2.7), and will decrease the public nuisance associated with them.
- Use of locally produced and manufactured products in sustainable buildings bolsters the local economy and provides jobs in the community (as well as reducing energy use and emissions caused by long-range transportation of goods).
- If sustainable design involves cleanup and use of a brownfield site, the community may benefit from the improved environmental conditions associated with the cleanup. It may also experience economic development associated with productive use of a previously unused site and the presence of a new set of workers who make financial transactions in the community. (The socioeconomic effects of sustainable buildings on community development, improved health due to lower pollution loads, and reduced infrastructure needs were discussed in Section 2.7.)

Research Summary 3-3: Energy-Efficiency Upgrades Offer Opportunities for Improved Building Security

The following table is the result of a recent effort by Lawrence Berkeley National Laboratory to assess the security implications of energy-efficiency measures (Harris et al. 2002).

Efficiency Opportunities			Security Issue*
Project Planning and Management			
Integrated design process*	Design objectives	Clearly define goals and minimum requirements for sustainability/efficiency and security as part of an organization's architectural programming	Con, Air, Ex, RR
	Architectural and engineering solicitation and contracting	Specify required expertise in sustainability and security when issuing the solicitation and use explicit criteria for selecting an architectural and engineering firm; include integrated design tasks in the contract	
	Design charrette	Allocate time and resources for integrated design charrette(s) at an early stage of design, including a broad range of participants	
Architectural Considerations			
Building envelope	Airtight barrier	Appropriately seal buildings to both resist chemical/biological penetration and provide weather-tightness	Air
	Insulation	Insulate walls to provide a secondary barrier and thermal savings	Air, Ex
	Impact-absorbing walls	Use innovative walls systems (multiple layers, openings, crumple zones) designed to absorb blast effects that can also reduce envelope heat transfer and control solar gain	Ex
	Thermal mass	Design earth berms for blast deflection, which can also provide thermal buffering	Ex
		Specify high-mass (concrete) construction, which allows active or passive use of thermal mass to reduce heating/cooling loads	Ex
	Shading devices	Design shading devices that can double as blast protection	Ex
	Vestibules	Use vestibules to help control building access while reducing infiltration of unconditioned outside air	Con, Air
Windows	Laminate films	Apply blast-damage-resistant laminate films to interior surface of windows with appropriate emissivity and visible light transmittance	Air
	Operable windows	Analyze appropriate response to threat (http://securebuildings.lbl.gov/)	Air, RR
	Protective screens	Use external protective screens that may also control unwanted solar gain	Ex
	Storm windows	Consider retrofitting storm windows with efficient (low-e, solar control) films	Air, Ex

Efficiency Opportunities			Security Issue*
HVAC Considerations			
Air systems	System design	Consider separating ventilation air systems from thermal distribution. Radiant cooling/heating with hydronic distribution offers added efficiency; smaller, ventilation-only fresh-air supply and dedicated exhaust systems are easier to control in an emergency.	Air, RR
		Provide larger ducts and efficient fans for rapid venting and energy savings in normal operation	Air, RR
		Use efficient ventilation systems (displacement ventilation, large ducts, etc.) to reduce space and energy requirements for upgraded filters	Air, RR
	Variable-speed drives	Provide capability for normal operation and rapid venting (variable-speed drives also allow for dynamic braking to stop fans faster in an emergency)	Air, RR
	Dedicated exhaust	Provide separate additional exhaust for emergency venting or for economizer operation, especially in high-risk areas such as entry vestibules, loading docks, and mail rooms	Air, RR
	Whole-building ventilation	Consider dual use of building purging systems (for smoke and also chemical contaminants) to provide nighttime "free cooling" during normal building operation	Air, RR
	Duct leakage	Specify, install, and commission (test) ductwork for low leakage	Air, RR
	Dampers	Provide dampers with rapid closure and low leakage	Air, RR
	Filtration	Use low-pressure drop filters at the filtration level needed	Air, RR
		Tightly seal around in-line filters	Air, RR
	Security barriers	Review impact of security barriers, such as additional doors, on normal air distribution	Con, Air
Water systems	Physical layout	Provide secure enclosures and minimize run lengths of piping	Air, Ex
		Increase pipe size	Ex
Control System Considerations			
Window controls	Operable window controls	Provide automatic and operator control for chemical/biological isolation and thermal comfort	Air, RR
	Shading control	Provide automatic and operator control for blast protection and shading	Ex, RR
Integrated controls	Interoperable systems	Use interoperable systems to integrate security controls with other building controls (HVAC, lighting, access, surveillance, fire/smoke)	Con, Air, Ex, RR
		Plan for future additions as new sensing capability is developed	Con, Air, Ex, RR

Efficiency Opportunities			Security Issue*
Control System Considerations (contd)			
HVAC controls	Individual control of fans, dampers	Provide for pressurized safety zones when needed	Air, RR
	Alternate filtration path	Provide parallel path through filter banks during chemical/biological attack	Air, RR
Wireless systems	Remote monitoring and control	Provide secure and redundant controls using wireless and web-based systems	Con, Air, Ex, RR
Monitoring	System status monitoring	Provide whole-building system monitoring to improve maintenance, normal operation, and critical monitoring during events	Con, Air, Ex, RR
Elevator controls	Integrate elevator controls with building control systems	Integrate elevator controls for emergency response to fire or chemical/biological events and for efficient operation. Make elevators controllable to allow implementation of peak-load strategies.	Con, Air, Ex, RR
Lighting Considerations			
Interior/ exterior lighting	Security lighting	Provide efficient lighting and lighting controls such as motion sensors	Con
		Integrate lighting into overall building controls	Con, RR
Interior	Daylight access	Minimize interior spaces without daylight access to improve visibility in daytime emergency evacuations	RR
Distributed Generation			
Backup generation	Combined heat and power; renewable fuels	To reduce power and fuel costs during non-emergency periods, upgrade emergency backup generation from diesel to renewable onsite power (photovoltaics, wind, biofuels) or a gas turbine, combined with heat recovery for space heat or hot water	RR
Site Planning			
Building site	Site design and landscaping to reduce heating and cooling loads	Add protective open space around structures to allow buildings to be oriented for passive solar features	Con, Ex
		Use larger setbacks to allow trees and plantings to directly shade buildings and buffer or channel prevailing winds, to provide evapotranspiration cooling, and to reduce urban heat-island effects	
	Physical barriers	Add berms and water features to provide blast protection and access control, as well as stormwater/erosion management	
Campus layout	Sustainable site planning and management	Plan for larger, multi-use sites to enhance security, create opportunities for efficient water use/recovery/ recharge and ground-source heat pumps, and allow better load matching for onsite combined heat and power, etc.	Con, Ex

Efficiency Opportunities			Security Issue*
Other			
Cyber – security	Computer standby power	Physically shut off power to computers at night and during unoccupied periods to save energy while reducing risk of unauthorized access to data and systems.	Con

* Con = control of access; air = airborne (chem/bio) threat; Ex = explosive threat; RR = response and recovery.
** For more details, examples, and useful links, see www.wbdg.org/design.