

Incorporating Occupational Safety and Health of Preventive Maintenance Workers into the Design and Operation of Green Buildings

Safe is the New Green

August 23, 2011

Mohamed Omar, Harvard University

Margaret Quinn, Bryan Buchholz, Ken Geiser, UMass Lowell

“I’ll have an ounce of prevention”



“I’ll have an ounce of prevention.”

Research Layout

Phase I

Are Green Building Features Safe for Preventive Maintenance Workers? Examining the Evidence

Phase II

Development of an Occupational Safety and Health Assessment and Rating System for Green Buildings (OSHARS-GB)

Phase III

Application and Evaluation of an Occupational Safety and Health Assessment and Rating System for Green Buildings

Background

- Sustainability/Green Interest
 - The American Recovery and Reinvestment Act, 2009 ~ \$70 billion
 - United States Green Building Council-LEED
 - As of 2009
 - 21,614 Registered Projects
 - 6,455 Certified Projects
 - 114 Countries

Background

- Very limited OSH research related to green buildings
- Increased OSH incidents, case reports
 - 2007-2008 City Center, NV green project, 6 construction worker fatalities
 - 2010 CA solar panel installation fatality
 - 2007 OR wind tower fatality and injury
 - 2009 NY triple fatality in a recycling facility
 - 2008 CA double fatality in a recycling facility
 - 2009 MA hospitalization of more than 100 people near a recycling facility

Phase I

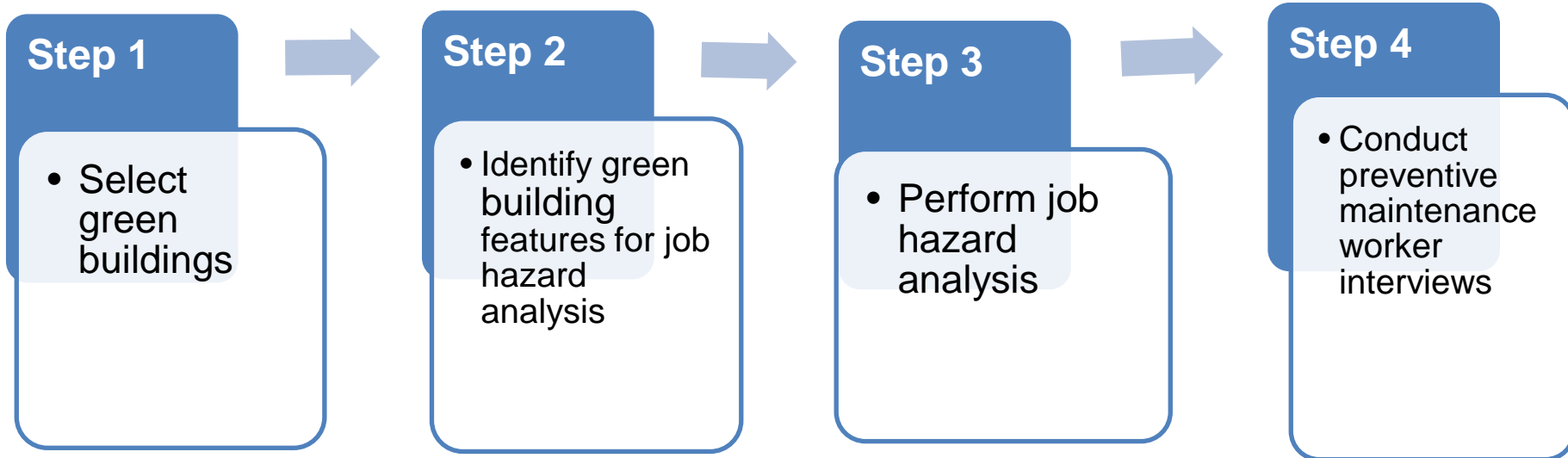
Are Green Buildings Features Safe for Preventive Maintenance Workers? Examining the Evidence

- **Objectives**

- ✓ To evaluate the OSH impact of selected ***green building features*** on preventive maintenance workers (PMW).
- ✓ The main premises are: 1) a green building should be safe for the people who maintain it, as well as for occupants and the environment; 2) safety is best assured by incorporating it into the building design phase.

Phase I

Overall Methodology



Phase I

- **Step 1: Select Green Buildings**
 - **Criteria for selecting study buildings**
 - ✓ The building has to be LEED certified,
 - ✓ The category of LEED certification has to be *New Construction and Major Renovations*.

Phase I Results

Description of the Thirteen Study Buildings^a

Study Buildings	Building Type	Size (square feet)	Year Construction Completed
Building A	Office	400,000	2006
Building B	Graduate student housing complex	208,343	2007
Building C	Graduate student housing complex	106,569	2008
Building D	Residence hall	48,218	2008
Building E	Residence hall	48,000	2006
Building F	Office	30,405	2006
Building G	Office	26,715	2008
Building H	Office	5,000	2006
Building I	Classroom complex	102,825	2006
Building J	Graduate student housing complex	229,000	2003
Building K	Office	93,923	2004
Building L	Library	24,000	2005
Building M	Office	36,080	2004

^a All buildings are located in the Northeast region of the U.S.

Phase I Results

Summary of Credits by Major LEED Category and LEED Certification Level for the Thirteen Study Buildings

Study Buildings	LEED categories with credit assignments						Total LEED Points	LEED Certification
	Sustainable sites	Water efficiency	Energy and atmosphere	Material and resources	Indoor environmental quality	Innovation and design process		
Building A	12	4	12	8	14	5	55	Platinum
Building B	13	2	7	6	8	5	41	Gold
Building C	13	3	3	6	12	5	42	Gold
Building D	10	3	12	5	14	5	49	Gold
Building E	9	3	6	9	12	5	44	Gold
Building F	11	3	6	6	9	4	39	Gold
Building G	9	2	13	7	13	5	49	Gold
Building H	10	3	5	7	14	5	44	Gold
Building I	9	2	4	3	10	5	33	Silver
Building J	9	0	11	5	5	3	33	Silver
Building K	11	0	6	2	3	4	26	Certified
Building L	7	1	5	6	6	4	29	Certified
Building M	8	2	5	7	8	1	31	Certified

Phase I

▪ **Step 2: Identify green buildings features**

- ✓ Must have contributed to LEED certification
- ✓ Must have ongoing preventive maintenance work
- ✓ Must be common feature, present in $\geq 15\%$ of the study buildings

Selected five green buildings features

1. Geothermal well system
2. Stormwater harvesting system
3. Energy recovery wheel
4. Green roof
5. Natural light percolating building features (skylights)

Phase I

- **Step 3: Job Hazard Analysis (JHA)**

- Focus on design related hazards, *OSH Design Hazard*
- Assign OSH Design Hazard Risk
 - ✓ OSH Design Hazard Risk = Probability Level x Severity Level

Phase I

Job Hazard Analysis Matrix (Partially Adapted from OSHA)

Green Building Feature Sub Components	Confined space	Electrical	Elevation/site train	Slips, trip, and falls	Fire hazard	Struck by/contact with unsafe object	Chemical exposure	Cold stress	Heat stress	High noise (>85 dBA)	Lifting hazards	Biological hazards	Awkward position	Forceful lifting, pushing, pulling	Prolonged repetitive motion	Vibration	Contact stress	Low light	Moving parts	High wind velocity	Unstable surface	Hidden drop-offs
Geothermal Well																						
Variable frequency drives																						
Strainers																						
Well pumps																						
Heat exchanger																						
Heat pump																						
Water treatment system																						
Expansion/pressure tank																						
Valence units																						
Compliance sampling																						

Phase I

Occupational Safety and Health Risk Scores Applied during Job Hazard Analysis (Adapted from U.S. Military System Safety Standard)

Hazard Probability			Hazard Severity		
Level Designation	Description	Score	Level Designation	Description	Score
Frequent	Likely to occur often in the life of an item, with a probability of occurrence greater than 1/10	5	Catastrophic	Could result in death, and/or permanent total disability	5
Probable	Will occur several times in the life of an item with a probability of occurrence less than 1/10, but greater than 1/100	4	Critical	Could result in permanent partial disability, injuries or occupational illness that may result in hospitalization	4
Occasional	Likely to occur sometime in the life of an item with a probability of occurrence less than 1/100, but greater than 1/1000	3	Marginal	Could result in injury or occupational illness resulting in one or more lost work days	3
Remote	Unlikely but possible to occur in the life of an item, with a probability of occurrence less than 1/1000, but greater than 1/100000	2	Negligible	Could result in injury or illness not resulting in a lost work day	2
Improbable	So unlikely, it can be assumed occurrence may not experienced with a probability of occurrence less than 1/1000000 in that life	1			

Phase I Results

Occupational Safety and Health Design Hazard Scores for the Geothermal Well System

	Slip, trip, and fall	Struck by/contact with unsafe object	Chemical exposure	Biological hazards	Working in awkward position	Forceful lifting, pushing, pulling	Rupture hazard	Low light
Geothermal System Components								
Variable frequency drives	15	15			15	10		
Strainers	15	15		15	15	15		
Well pumps	15	15			15	15		
Heat exchanger	15	15				15		
Heat pump	15	15	20		15	15		15
Water treatment system	15	15	20					
Expansion/pressure tank	15	15			15		20	
Valence units	15	15	20	15	15			
Compliance sampling	15	15	20					



Phase I Results

Occupational Safety and Health Design Hazard Scores for the Stormwater Harvesting System

	Confined space	Elevation/site train	Slip, trip, and fall	Struck by/contact with unsafe object	Chemical exposure	Lifting hazards	Electrical hazard	Awkward position	Low light
Stormwater Harvesting System Components									
Underground Irrigation Tanks (two 15,000 gallons)	12			15				15	15
Rain Sensors		15	15	15				15	
Stormwater Holding Tank	20	15	15	15				15	15
Re-pressurization Pumps			10	15		15	15	15	
Re-circulating Water Loop Pump			10	15		15	15	15	
Bag Filters			10	15				15	
Ultraviolet Sterilization Treatment System			10	15				10	
Bleach Chamber			10		15				
Chemical Dye Chamber			10		15				

Phase I Results

Occupational Safety and Health Design Hazard Scores for the Energy Recovery Wheel

	Confined space	Electrical hazard	Struck by/contact with unsafe object	Low light	Awkward position
Energy Wheel System Components					
Wheel Cassette	20	15	15	10	15
Filters	20	15	15	10	15
Perimeter Seal	20	15	15	10	15
Velcro Seam	20	15	15	10	15
Wiper Seal	20	15	15	10	15
Drive Belt	20	15	15	10	15
Drive Motor	20	15	15	10	15
Drive pulley	20	15	15	10	15
VFD			15		15
Cooling/heating coil	20	15	15	10	15

Phase I Results

Occupational Safety and Health Design Hazard Scores for the Green Roof

	Slips, trip, and fall	Working at an elevated site	High wind velocity
Green roof system components			
Roof Inspection for:			
Drains and gutters	25	10	10
Kitchen vent	25	10	10
Trash compactor vent	25	10	10
Laundry room vent	25	10	10
Toilet exhaust	25	10	10
Trash compactor vent	25	10	10
General Roof Access for:			
Maintenance and repair of heating and cooling equipment at the roof.	25	10	10

Phase I Results

Occupational Safety and Health Design Hazard Scores for the Skylights and Glazed Building Areas

	Elevation/site train	Slip, trip, and fall	Awkward position	High wind velocity
Skylights & Glazed Areas Components				
Barrel Vault Skylight	10	25	10	10
Shed Skylight	10	25	10	10
Windows & Glazed Areas	10	25	10	10

Phase I Results

- **Step 4: Preventive maintenance worker interviews (n= 6)**

- √ Perform preventive maintenance in one of the green buildings in the study
- √ Perform preventive maintenance in non-green buildings
- √ Perform preventive maintenance on at least one of the green building features in the study

- **Preventive Maintenance Worker Interview Participants Profiles**

Interview Participant No.	General PM Experience (Years)	Green Building Features PM Experience (Years)	Weekly Work Schedule (Hours)
1	36	4	40
2	11	2	40
3	24	4	40-50
4	25	1.5	40-50
5	23	3	40
6	20	3	40
Total	139	17.5	260

Phase I Results

Preventive Maintenance Worker Interview

Question Domain	No. of Preventive Maintenance Workers		
	Yes	Neutral	No
<i>Environmental Benefits Awareness</i>			
General awareness of the environmental benefits of the green building features	6		
Specific knowledge of the environmental benefits of the green building features	5		1
<i>Health and Safety Concern</i>			
Occupational health and safety concerns related to the maintenance of the green building features	5		1
Personal injury or illness during maintenance of the green building features	2		4
The identified occupational health and safety concerns are not all unique to green buildings	6		
<i>Engineering and Administrative Controls</i>			
More engineering controls in green building features than in conventional building mechanical systems	1		5
Specialized trainings are needed to maintain green building features		2	4
Special or more personal protective equipment are used in green building features		2	4

PM = Preventive Maintenance

Neutral = Interview participants outsource some of the preventive maintenance to outside vendors, and have no specific answer to the these questions

Phase I: Conclusions and Recommendations

- Certain green building features that are designed to reduce negative environmental impact and improve building occupant experience pose OSH
 - In general green building features are not safer than non-green building systems for PM workers.

- Most of the observed OSH risk in the green building features can also be found in non-green buildings.

- The most problematic OSH findings include:
 - Slip, trip and fall hazard of green roofs that are made of slippery membrane material with no fall protection mechanism
 - Energy recovery wheels and stormwater harvesting systems that are located in a confined spaces

- The results of this study supported the need for incorporating OSH considerations into the design of green buildings.

Phase II

Development of Occupational Safety and Health Assessment and Rating System for Green Buildings (OSHARS-GB)

▪ Objectives

- ✓ To incorporate occupational safety and health into the design of green building features by introducing a simple, but effective occupational safety and health system for green building Preventive Maintenance Workers (PMW).

- ✓ The proposed rating system is very specific to five green building features that are commonly used in green buildings:
 1. geothermal well,
 2. energy recovery wheel
 3. storm water harvesting system
 4. green roof
 5. building infrastructures that are designed to bring natural light e.g. skylights and large glazed building façade

Phase II

Overall Methodology



Phase II Results

Hazard Categorization

OSH Design Hazard Category	Operating System with OSH Hazard Potential
-----------------------------------	---

Green Building Feature

Rainwater Harvesting System

Electrical hazard	Re-circulation water loop pumps, and re-pressurization pumps.
Confined space slip, trip, and fall	Stormwater collection and holding tanks Rain sensors, bag filters, pumps, storm water holding tank, UV system
Working at an elevated site Struck by an object	Rain sensors, storm water holding tank Bag filters, pumps, rain sensors, storm water holding tank.
Chemical exposure	Disinfectant, and dye chambers
Lifting hazard	Pumps
Working in an awkward position	UV system, bag filters, pumps, rain sensors, storm water collection and holding tanks
Low light	Underground storage tanks

Phase II Results

Overview of the proposed Occupational Safety and Health Assessment and Rating System for Green Buildings (OSHARS-GB)

Occupational Safety Assessment Tool Core Elements					
Green Building Feature	OSH Design Hazard Category	Operating System with OSH Hazard Potential	OSH Performance Goal	OSH Hazard Score	OSH Prevention Score
Geothermal well	Slips, trips, falls	Variable frequency drives, strainers, pumps, heat pumps, heat exchangers, chemical feed ports, valence units, water sampling ports, and pressure tanks.	The geothermal well, and all associated mechanical equipment take into account safe serviceability and ease in access and reach that avoids slip, trip and fall hazards.		
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-

Green building feature OSH overall rating

Phase II Results

Occupational Safety and Health Assessment and Rating System for Green Building (OSHARS-GB), Geothermal Well

The geothermal well rating system promotes a safe and healthy preventive maintenance of the geothermal well system and equipment. It presents a series of occupational safety and health (OSH) Performance Goals related to slips, trips, falls; being struck by an object; chemical and biological exposure; working in an awkward positions; forceful lifting, pushing, and pulling hazards; and low light. A geothermal well that scores higher indicates safer work place for preventive maintenance workers.

OSH Design Hazard Category	Operating System with OSH Hazard Potential	OSH Performance Goal	OSH Hazard Score	OSH Hazard Prevention Score	Result	Comments
Slips, trips, and falls	Variable frequency drives, strainers, pumps, heat pumps, heat exchangers, chemical feed ports, valence units, water sampling ports, and pressure tanks.	The geothermal well, and all associated mechanical equipment take into account safe serviceability and ease in access and reach that avoids slip, trip and fall hazards.	Select... ▼	Select... ▼		
Struck by object	Variable frequency drives, strainers, pumps, heat pumps, heat exchangers, chemical feed ports, valence units, water sampling ports, and pressure tanks.	The geothermal well and all mechanical equipment have been designed and spaced in such a way that all system components are away from obstructions and can be safely serviced without the worker being struck by an object	Select... ▼	Select... ▼		
Working in awkward position	Variable frequency drives, strainers, pumps, heat pumps, heat exchangers, valence units.	The geothermal well and all mechanical equipments have been designed and spaced in such a way that all system components can be serviced without working in an awkward position.	Select... ▼	Select... ▼		
Chemical exposure	Heat pumps, water treatment system, valence units, and water sampling ports.	The geothermal well and all associated systems have been designed with no, or less harmful and safe chemical treatment needs.	Select... ▼	Select... ▼		
Biological exposure	Strainers and valence units.	The geothermal well and all associated equipments have been designed with materials and processes that are less prone to biological material growth.	Select... ▼	Select... ▼		
Rupture hazard	Expansion tank.	The expansion tank has been located in an area that is less prone to flooding and corrosion to avoid or minimize tank rupture.	Select... ▼	Select... ▼		
Forceful lifting, pushing and pulling	Pumps, strainers, heat exchangers.	All pumps have been designed and located with the ability to be safely serviced without the need for heavy lifting, pushing and pulling.	Select... ▼	Select... ▼		
Low light	Heat pumps.	Well lit work place area has been provided.	Select... ▼	Select... ▼		

Overall Rating = Sum of all Results

OSH Hazard Score Guide. How well does the operating system meet OSH Performance Goal? : Very well (4), moderately well (3), somewhat (2), and, not at all (1)

OSH Hazard Prevention Score Guide. How effective are the existing or proposed preventive measures? : Elimination of hazard through re-design (4), substitution of hazard (3), engineering controls (2), and, administrative control, e.g. warning sign (1).

Result = Obtained by multiplying OSH Hazard Score with OSH Hazard Prevention Score

Overall Rating: Severe OSH hazard (0-30th value), moderate OSH hazard (31-55th value), minimal OSH hazard (56-86th value), and, no OSH hazard (> 87th value).

Phase II: Conclusions and Recommendations

- OSH professionals in this study strongly suggested that the safety and environmental fields would benefit from a rating system that integrates environmental stewardship and worker safety.
- The proposed rating system promotes the concept “prevention through design” in that it assists designers, builders, and operators to identify unsafe design features and rewards green designs that prevent OSH hazards.
- The proposed rating system is compatible with the LEED rating system. OSHARS-GB can be used with LEED or as stand alone assessment tool.
- The proposed rating system promotes interdisciplinary teamwork in designing and operating green buildings and integrates the concepts of environmental sustainability and OSH.

Overall Recommendations

- Develop a collaborative project with the USGBC.
- Promote interdisciplinary approaches in the design of green buildings.
- Build on the OSH findings of the five green building features in this study to include additional green building features considered for green buildings or LEED certification.
- Investigate the possibility of integrating OSHARS-GB with existing tools for the selection of safe building products:
 - OSHA Program Evaluation Profile,
 - Pollution Prevention Options Analysis Systems,
 - Pharos Project.
- Create OSH issues awareness and training for architects, engineers, builders, and operators involved in green buildings.
- Develop educational material and courses that promote environmental protection and community and worker safety collectively into the concepts of sustainability and green buildings.

Thank You!

Safe is the New Green

