Evaluating the health and safety practices for the delivery of building energy retrofit projects in South Africa

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Abstract. Implementing energy upgrades in buildings will bring about economic gains, while enhancing social wellbeing and engendering sustainable development. However, building energy upgrades encompass additional considerations and requirements in terms of processes, materials, and expertise, technology and health and safety practices. All these factors constitute complexities in the delivery of the project. In addressing this problem; the paper presents how stakeholders understand health and safety issues in the delivery of projects amongst South African service providers. The case-based study highlighted the health and safety issues, and solutions concerning the methodologies that are appropriate in enhancing the conditions.

Keywords: Building, CO₂ emission, Energy, Health and Safety, Retrofit and Sustainable development.

1. Introduction
The design, construction, operation and maintenance of building energy retrofits can impact the air we breathe, our energy consumption, and our health. Building energy retrofit has proven to aid carbon emission (CO₂) reduction in the existing building. However, BERP may worsen existing indoor environmental problems and indoor air quality. It may also introduce new problems as the frequency or severity of adverse outdoor conditions changes. To protect the occupants in buildings and maintain safe and healthy indoor environments, considerations for building energy retrofits should be made. Such considerations should include occupant health, wellbeing and safety [1].

Building energy retrofits can be broadly categorised as an energy conservation measure in an existing building that leads to an overall improvement in the building energy performance. While there is no exact definition for a deep energy retrofit, [2] and [3] defined it as a whole-building analysis and construction process that aims at achieving on-site energy use minimization in a building by 50% or more compared to the baseline energy use (calculated using utility bills analysis) making use of existing technologies, materials and construction practices. Such retrofit projects reap manifold (energy and non-energy) benefits to the client [3, 4].

BERPs have different phases governing them, such as pre-planning, project planning, construction, and test out [3, 5]. It has been documented that retrofitting existing buildings is more challenging, than designing a new sustainable building from scratch [6, 7]. This challenge is due to uncertainties such as climate change, human behaviour, technology and expertise which have impact on project success. Furthermore, building is a complex system, consisting of highly interactive components. Therefore, the evaluation of the effects induced by building energy retrofit measures (BERMs) on building
behaviour is critical in assessing the H&S of the occupants. Sequel to this background, the paper highlights the health and safety challenges and solutions that are appropriate in combating this problem in the South African Built Environment Sector.

2. Literature Review
The built environment has been described as the major contributor to CO2 emissions [8, 9]. In support of the above view, [10] posited that existing buildings are responsible for 35% of final energy consumption, with the majority of the energy being used to power HVAC systems, and office equipment. Energy is the primary component contributing towards the operating costs of buildings [8, 9].

The phenomenon of climate change is responsible for the current focus on carbon management as one must be mindful of the wider implications of CO2 emissions for sustainable development, and the role that the built environment plays in this interaction [11]. According to [12], 82% of final energy consumption in buildings was supplied by fossil fuels in 2015 and that deep energy retrofitting in existing building stocks is critical in achieving the global climate goals laid down in the Paris Agreement.

Deep energy retrofits require a systems-thinking approach than the traditional approach followed for a conventional retrofit. Typically, conventional energy retrofits focus on isolated system upgrades (i.e. lighting and HVAC equipment), whereas deep energy retrofits achieve much greater energy efficiency by taking a whole-building approach, thereby addressing many systems at once. It is most economical and convenient to take this approach on buildings with overall poor efficiency performance, with multiple systems nearing the end of useful life, and perhaps other reasons [12]. There have been several studies done to determine and quantify the benefits afforded to owners, tenants, and various other stakeholders from the successful completion of deep energy retrofits. The following tabulation by the Rocky Mountain Institute lays the efficiency measures undertaken in a deep energy retrofit project in correspondence to building performance improvements and therefore, the quantifiable and non-quantifiable values generated from implementation of such projects [13].

In addition to the benefits accrued in deep energy retrofits, there are several occupational H&S (OHS) risks associated with the planning, construction, and operation of BERPs. These OHS risks are new compared with traditional construction sites. This can be attributed to green materials, technologies or processes being adopted in delivering of BERPs. Generally, retrofitted buildings are considered safe and healthy working environments. However, the potential for indoor air quality problems, occupational illnesses and injuries, exposure to hazardous materials beckons on BERP experts to deliver BERPs that are compliant to OHS regulations. As a result, protecting the OHS of workers and building occupants has now become paramount. The quest justifies the need for this study in South Africa.

| Serial No | Deep Energy Retrofit Efficiency Measure | Building Performance | Value |
|-----------|----------------------------------------|----------------------|-------|
| 1         | Envelope                               | Thermal comfort      | Reduction in cost |
|           | • Insulation                           | Active occupant       | • Lower maintenance cost |
|           | • Windows                              |                      | • Lower health cost (absenteeism, health care) |
|           | • Air tightness                        |                      |       |
| 2 | Passive Design |
| --- | --- |
| • Green/white roof | Environmental Control |
| • Natural ventilation | Indoor air Quality |
| • Day lighting | Visual acuity and comfort |
| • Landscaping | Green building rating or score |
| | Views to the outdoors |
| 3 | Electric Lighting |
| • Fixtures upgrade | Space efficiency |
| • Controls | Space flexibility |
| • Redesign |  |
| 4 | Plug Loads & Misc. |
| • Efficient equipment | Compliance with |
| • Controls | Internal and External Policies/Initiatives |
| 5 | Heating, Cooling, & Ventilating |
| • Demand control ventilation | Reduced Risk to Future |
| • Digital controls | • Lower employee recruiting and churn costs |
| | • Revenue Growth |
| | • Higher occupancy rates |
| | • Higher rents |
| | • Increased employee productivity |
| | • Improved marketing & sales |
| | • Recruiting best employees or tenants |
| | • Employee or tenant satisfaction and retention |
| | • Public relations/brand management |
| | • Retain “social license” to operate |
| | • Meet needs of Global Reporting Initiative, Corporate Social Responsibility, Carbon Disclosure Project |
| | • Meet responsible investment fund requirements |
| | • Meet growing Securities and Exchange Commission regulations |
| | • Reduced risk from energy disclosure mandates |
| | • Limit exposure to |
3. Research Methods
The study utilised a qualitative approach whereby service-providers were interviewed with questions that revolve around the OHS of workers, and the wellbeing of occupants in the delivery of BERPs. The choice of a qualitative approach was premised on the fact that qualitative research methods allow for in-depth and further probing and questioning of interviewees based on their responses. According to Gray [13] and [14], there are different types of qualitative research methods; these include in-depth interviews, focus groups, ethnographic research, content analysis and case study research. This study adopted in-depth interviews and a case study research design. In realisation to this objective, the case study projects were identified and selected. The relevant professionals responsible for the retrofitting of these cases were interviewed to elicit their perceptions of the implications of BERPs on workers’ and occupants’ OHS. The main criteria used were the evidence of successful completion of deep BERPs in South Africa and the willingness of the service providers to participate in the exercise. These selection criteria led to the identification of four case studies and seven interviewees. A description of the case studies is provided in Table 2 and the profile of the interviewees is provided in Table 3.

Table 2. Description of Case Studies

| Serial number | Location      | Type of building                  |
|---------------|---------------|-----------------------------------|
| 1             | Bloemfontein  | Government administrative building |
| 2             | Cape Town     | Government administrative building |
| 3             | Cape Town     | Multi-purpose office complex       |
| 4             | Johannesburg | Hotel facility                     |

Source: Authors’ fieldwork (2019)

The central objective of the case study (case interview sessions) was to gather information pertaining to the practical experiences of relevant stakeholders who have been involved with the specific BERPs whilst also reviewing the utility of most of the operational facets that will lead to OHS issues. These interviews were held at the offices of both organisations who had delivered the case project. The interview sessions lasted for an average of 45 minutes each. The sessions were tape recorded with permission from the interviewees and transcribed verbatim for analysis and the table below shows the profile of the interviewees.
Table 3. Interviewee’s Demographics

| Interviewee | Position       | Experience in Years (retrofit trade) |
|-------------|----------------|-------------------------------------|
| PS1         | Director       | 22                                  |
| PS 2        | Director       | 19                                  |
| PS 3        | Senior Manager | 14                                  |
| PS 4        | Energy Manager | 20                                  |
| PS 5.       | Energy Manager | 17                                  |
| PS 6.       | Energy Manager | 19                                  |
| PS 7.       | Energy Manager | 8                                   |

Source: Authors’ fieldwork (2019)

The recording device allowed the researcher the opportunity to concentrate fully on the responses, although notes were also taken during and after the recording. These notes were taken into account during data analysis. Each interview was transcribed and underwent a series of coding exercises related to themes, relationships, and differences regarding the subject matter during data collection and analysis. Extensive reading on the research topic was done to ensure understanding of the context and to capture perspectives from the participants. This included revisiting and reviewing the interview transcripts to ensure that the emphasis on the topic was accurately captured.

4. Presentations of findings

The participation of the interviewees in these cases is paramount for obtaining in-depth knowledge on the study. The sample of interviewees comes from different organisations, background and experience. This ensured diverse views on the subject matter. A purposive sample was adopted. The interviewees have an average of 17 years of experience in BERPs. This presentation format is expected to enable coherence and streamlining of the data emerging from different sources.

Table 4. Matrix of activities that gave rise to OHS challenges with solutions.

| Activity                        | Occupational health and safety issues                                                                 | Solutions                                                                 |
|--------------------------------|-------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Upgrading lighting fixtures to save energy. | - Asbestos-containing material, lead paint or poly chlorinated biphenyls (PCBs) may be disturbed during lighting replacement. PCBs may be present in older fluorescent light ballasts that are not labelled “No PCBs” or “electronic.” | Remove and replace old fixtures containing hazardous materials with those that contain less hazardous materials. Properly dispose of lamps containing mercury and fixtures containing PCBs. |
|                                | - Mercury vapour or mercury-containing powder from broken fluorescent bulbs or improper use of drum-top crushers may be present. |                                                                            |
|                                | - Lighting upgrades likely will reduce sensible heat loads, which may affect moisture removal performance of the HVAC system. |                                                                            |
| Activity                              | Occupational health and safety issues | Solutions                                                                 |
|--------------------------------------|--------------------------------------|---------------------------------------------------------------------------|
| Upgrading roof and ceiling insulation | Asbestos-containing material, lead paint, PCBs or mold may be disturbed. • Installing spray-polyurethane foam may generate indoor contaminants. • Moisture may be trapped behind spray foam insulation when installed under a low pitch wooden roof deck, creating the potential for hidden, structural roof damage and mold. • Moisture may be trapped in insulation installed below drainage planes, vapor barriers or roof membranes (in cold climates). • Sealing the building envelope may increase levels of indoor contaminants, including radon, combustion by-products, moisture and mold, and volatile organic compounds (VOCs). | Control for moisture by selecting moisture resistant insulation, properly installing insulation materials, and ensuring surfaces and assemblies with condensation potential are properly sealed and insulated to avoid dew-point conditions. • Seal unwanted openings and leaks in the building envelope to reduce infiltration and conditions conducive to pest entry. Adequate ventilation must be provided to dilute and remove indoor pollutants. Radon mitigation systems may become necessary. |
| Upgrading wall insulation             | Asbestos-containing material, lead paint, PCBs or mold may be disturbed. • Installing spray-polyurethane foam may generate indoor contaminants. • Sealing the building envelope may increase levels of indoor contaminants, including radon, combustion by-products, moisture and mold, and VOCs. | Control moisture and condensation potential on surfaces; install moisture-resistant insulation; and ensure proper exterior drainage and water management (e.g., include header and panned windowsill flashing during window replacement). • Seal unwanted openings and leaks in the building envelope to reduce infiltration and conditions conducive to pest entry. Adequate ventilation must be provided to dilute and remove indoor pollutants. Radon mitigation systems may become necessary. |
| Modifying or repairing existing moisture barriers | Asbestos-containing material, lead paint, PCBs or mold may be disturbed. • Uncovered dirt floor may contribute to excessive moisture migration into the building. • Installing carpet or floor tile over concrete floor that has a persistent condensation or water pooling problem | Provide sealed moisture barrier over dirt foundation floors. • Provide moisture barrier beneath concrete slabs. • Select sealants/adhesives with low-VOC or no-VOC content/emissions. • Select |
### Activity | Occupational health and safety issues | Solutions
--- | --- | ---
Activity | Occupational health and safety issues | Solutions
will likely lead to mold growth. • An existing moisture barrier may also be an integral part of a radon mitigation system or other belowground contaminant mitigation measures and should not be disturbed. • Uncovered dirt floors may introduce pest populations and will promote rodent habitats. | exposed poly films with proper flame and smoke ratings. • Incorporate other radon mitigation and belowground contaminant mitigation measures as needed.

### Pipe modifications:

- Asbestos-containing material, lead paint or mold may be disturbed during system or component replacement. • Improperly vented combustion gases and occupant exposure to CO₂ are potential risks. • Moisture or mold may be present when the HVAC system is turned off for extended periods of time. • Poor humidity control during cooling system operation can result in mold growth and present opportunities for pest infestations. • Inappropriate use of chilled water reset or

- Asbestos-containing material, lead paint, mold or other debris may be disturbed during duct installation, sealing or replacement. • Improper condensate drainage can present an opportunity for Legionella, bacterial or mold growth in units with cooling coils. • Humid climates may require additional dehumidification when the outdoor air supply is increased. • Ductwork that is not properly sealed and insulated can lead to condensation problems if it passes through unconditioned spaces. • Improper modifications to HVAC systems can cause unbalanced flows and pressures that can lead to increased intrusion of moisture, radon and other belowground contaminants. • Excessive moisture promotes pest infestation. • HVAC components may be contaminated with PCBs if PCBs have migrated via indoor air from caulk and/or lighting ballasts that contain PCBs.

- Properly vent combustion gases and ensure that mechanical rooms with combustion equipment have adequate make-up air and ventilation. • Install and maintain CO₂ detection and warning equipment. • Ensure that steam traps, combustion equipment and boilers are installed correctly and that make-up air registers are not blocked. • Ensure that air

- Converting from one-pipe to two-pipe steam systems OR

- Converting from - to four-pipe heating and cooling systems

- Reduce entry of airborne contaminants into the building; maintain interior humidity levels. • Select low-VOC and formaldehyde-free products. • Provide sealed and energy-efficient ducts. • Provide proper ventilation; properly balanced HVAC systems can maintain positive pressurization indoors to reduce intrusion of moist air into the building envelope and interior zones and below-ground contaminants and radon into the building.

- Contain and do not disturb areas of significant mold contamination until these areas can be remediated. • Reduce entry of airborne contaminants into the building; maintain interior humidity levels. • Select low-VOC and formaldehyde-free products. • Provide sealed and energy-efficient ducts. • Provide proper ventilation; properly balanced HVAC systems can maintain positive pressurization indoors to reduce intrusion of moist air into the building envelope and interior zones and below-ground contaminants and radon into the building.

- Select low-VOC and formaldehyde-free products. • Provide sealed and energy-efficient ducts. • Provide proper ventilation; properly balanced HVAC systems can maintain positive pressurization indoors to reduce intrusion of moist air into the building envelope and interior zones and below-ground contaminants and radon into the building.
### Activity

| Occupational health and safety issues | Solutions |
|--------------------------------------|-----------|
| Airside economizers can lead to cool and clammy conditions and condensation on cold surfaces. • Inadequate humidifier maintenance can lead to microbiological problems. • HVAC components may be contaminated with PCBs if PCBs have migrated via indoor air from caulk and/or lighting ballasts that contain PCBs. | Conditioning systems are properly sized and controlled to avoid humidity and moisture issues, particularly under partload conditions, and properly sized for both cooling and dehumidification. • Ensure that well-maintained humidification equipment and controls are in place to promote occupant comfort and health during the heating season, as needed. |

### HVAC Controls to monitor/maintain indoor air quality (IAQ) (upgrades or modifications)

- Asbestos-containing material or lead paint may be disturbed during wall or ceiling penetrations. • Mercury from removal of old mercury bulb thermostats may present a risk. • Sensors that are not regularly calibrated may lead to IAQ problems. • Poor humidity control during cooling system operation can result in mold growth and present opportunities for pest infestations. • Inappropriate use of chilled water reset, or airside economizers can lead to cool and clammy conditions and condensation on cold surfaces. Indoor air can become too dry for occupant comfort and health during the heating season, particularly in northern and high-altitude locations. • Inadequate operation and maintenance of humidifier controls can lead to microbiological problems. • Improper HVAC controls can cause unbalanced flows and pressures that can lead to increased intrusion of moisture, radon and other belowground contaminants. Improperly vented combustion gases; occupant exposure to CO₂.

- Control moisture to avoid mold growth and pest infestations and optimize occupant comfort. • Ensure that well-maintained humidification equipment and controls are in place to promote occupant comfort and health during the heating season, as needed. • Monitor and maintain outdoor airflow rates. • Install and maintain CO₂ detection and warning equipment. • Properly dispose of mercury-containing thermostats.

Source: Researchers, 2020
5. Discussion of findings

The climax of the study reveals that virtually every item of work in BERPs has occupational health and safety challenges. This ranges from de-lamping to HVAC. As the respondents emphasise strongly the need for the integration of energy efficiency upgrades and their occupational health and safety challenges, both should be critical priorities for BERPs. The interviewees suggested that often times the health and safety needs of occupants are deliberately ignored in the delivery of BERPs but supported the holistic unification of energy efficiency abatement and occupational health and safety goals in delivering of BERPs. The built environment is critical to both of these concepts of ‘sustainable development’, and therefore the management of carbon in the built environment and subsequent improvement in the area of occupational health and safety of the occupant is central to the efforts to bequeath a ‘sustainable’ world to future generations [11]; [16]; [17].

The study found that in adding window film covering or sealing of windows in energy efficiency upgrades, there will usually be increased levels of indoor contaminants, including radon, combustion by-products, moisture and mold which also coincide with the findings of [17]. It further found that it is important to seal unwanted openings and leaks in the building envelope to reduce infiltration and conditions conducive to pest entry. The study further revealed that during HVAC upgrades poor humidity control can result in mold growth and present opportunities for pest infestations. Inappropriate use of chilled water reset, or airside economisers can lead to cool and clammy conditions and condensation on cold surfaces. The authors reiterated that most times such work is neglected thereby causing health hazards to the occupants. The study suggested that experts dealing in BERPs should obtain substantial benefits from being flexible, by applying learning through continuous improvement and administrative innovation, because no two BERPs are the same. Emphasis was laid on collaboration during energy efficiency EE initiatives that allow solving problems creatively for better outcome for the building and occupants [18]. These collaborative meetings can help to identify synergies between building systems that can significantly reduce energy consumption, promote health and safety of the occupants and provide cost savings. For best results, [11] accentuate that the service provider should establish cross-functional team meetings from the very beginning of project planning and continue meetings regularly through to project completion.

6. Concluding remarks

By understanding the relationship between building energy retrofits and occupational health and safety, stakeholders can potentially realise substantial improvements in this trade. The study reported that energy efficiency upgrades can have negative impacts on occupants’ health and safety. With an increase in EE initiatives in building, consideration should be given in integrating energy upgrades with appropriate health and safety measures. By addressing health and safety measures at the beginning of EE drives in building, greater energy savings can be achieved per house, pollutant exposure problems can be avoided, and public health can be protected. It also means decreasing the potential risks of additional costs to resolve health and safety problems related to retrofit activities, which decrease productivity and increase business costs for the retrofit trade.

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