Energy Efficiency Building retrofitting and maintenance in Africa for bigEE

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Table of contents

Abbreviations and acronyms

Abbreviation/acronym	Description
EE	Energy Efficiency
BAT	Best Available Technologies
POET	Performance, Operation, Equipment and Technology
ECM	Energy Conservation Measure
ESCo	Energy Services Company
M&V	Measurement and Verification
PM	Preventive Maintenance
SANS	South African National Standards

The objective of this energy efficiency (EE) document is to provide useful information of the best available technologies (BAT) of existing plug devices in office buildings in the South African and international markets.

1 Introduction

1.1 The scope of Retrofitting and Maintenance

In this document, the building energy efficient retrofitting and maintenance planning technologies and practices are introduced. The building energy efficient retrofitting is the process of implementing energy conservation measures (ECMs) to the existing building for energy efficiency purposes. The retrofitting planning is a complicated decision making process, involving the auditing of existing building, the organization of different categories of energy efficiency technologies and equipment, the multi-objective optimization with a couple of different performance indices, and the post-implementation evaluation.

The maintenance is another important category towards building energy efficiency and sustainability. In the energy efficiency context, maintenance not only improves the reliability of the equipment, bust also restores the energy efficiency against the deteriorations that are inevitable during operation. The energy efficient maintenance planning is also a complicated decision making process when taking into account the long-term energy and economy performances in a retrofitted building.

This document of building energy efficient retrofitting and maintenance practices is provided in terms of the technology, equipment, operation, and performance (POET) framework. The contents are classified when possible in groups of South Africa available practices and International available practices.

The feasibility of using energy efficient retrofitting technologies shall be to be evaluated based on the investment cost incurred to achieve energy saving and resulting cost saving. An easy and quick decision making indicator is the payback period. A maximum payback period should be fixed for each energy efficiency technology or optimal component design. The energy efficiency technology or optimal component design will therefore be used if the corresponding payback period does not exceed the maximum acceptable payback period.

2 POET Framework for Retrofitting

2.1 Retrofitting technology

2.1.1 Pre-retrofitting audit

A. International available technologies: The energy audit is the basis of building energy efficient retrofitting decision making. Typically, an energy service company (ESCo) collects information

corresponding to the retrofitted building to ensure the success in various ways. Taking advantage of the collected information, the engineering analysis is performed to figure out the feasible retrofitting plan taking into account all possible risks. Energy audit is an important step used by the ESCo to ensure the success of their performance contracting projects (Krarti, 2011).

B. South Africa available technologies: same as international technologies.

2.1.2 Building energy simulation

A. International available technologies: Building energy simulation predict the energy performances of the building based on the building information model and thermal simulation engines. Taking advantage of the simulations, energy consumptions for different design alternatives can be predicted and analyzed. The simulation results support the retrofitting decision making.

B. South Africa available technologies: Same as international technologies.

2.1.3 Retrofitting planning

A. International available technologies: By pre-retrofitting auditing and simulation, the available retrofits can be identified. Thereafter, following information can be obtained: the energy consumptions of alternative interventions, the capitals of purchase and install equipment needed, the further impacts on environment, the occupants comfort changes. The retrofitting planning is interpreted to be an optimization problem that strikes a balance among several objectives: the minimized energy consumptions, the minimized capital costs, the positive environmental impacts and occupant satisfactoriness. The energy consumption and capital investment are the most widely used objects (Asadi et al., 2012).

B. South Africa available technologies: Based on the measurement and verification (M&V) principles, the energy savings of the alternative interventions against the baseline energy performances are obtained. Thereafter, the corresponding cost savings can be calculated. Furthermore, the energy and cost savings can reduce due to the failures among equipment. The maintenances can result in additional cash outflows during operation. All the aforementioned facts and effects are taken into account to formulate an improved optimization model that maximizes the aggregate energy savings and minimize the payback period of a retrofitting project during a specific period. The new optimization model can provide more comprehensive support to the decision maker (Wang, Xia and Zhang, 2014).

2.1.4 Post-retrofitting activities

A. International available technologies: Post-retrofitting survey and retrofit reports are required after implantation to evaluate the effectiveness of the retrofitting project. Furthermore, the M&V methodology provide a systematic way to evaluate an energy efficiency project.

B. South Africa available technologies: M&V practices are widely used in South Africa (Xia and Zhang, 2013).

2.1.5 Recommendation and Comments

There are many valuable practices in South Africa.

2.2 Retrofitting equipment

2.2.1 Energy audit categories

A. International available practice: The pre-retrofitting energy audit includes: walk through audit, utility cost analysis, standard energy audit, detailed energy audit.
B. South Africa available practice: Smartphone app based energy audit utilities.

2.2.2 Building simulation tools

A. International available practice: Building energy simulation includes the building modelling, the thermal simulation engine and the user interface. Typical building modelling tool includes: SketchUp, AutoCAD, Revit. Typical energy simulation tools include: Energy plus, DOE2. Typical user interface includes: eQuest, RIUSKA, DesignBuilder (Maile, Fischer and Bazjanac, 2007).
B. South Africa practice: same as international practice.

2.2.3 Alternative interventions categorization

A. International available practice: N/A
B. South Africa available practice:
   - Lighting system;
   - HVAC system;
   - Water heating system;
   - Plug device system;
   - Building envelope;
   - Renewable energy system;

2.2.4 Recommendation and Comments

International available practice shall be used.

2.3Retrofitting operation

2.3.1 Implementation

A. International available practice: N/A
B. South Africa available practice: N/A.

2.3.2 Recommendation and Comments

N/A.

2.4Retrofitting performance

2.4.1 Green building ratings

A. International available practice:
   - Leadership in Energy and Environmental Design (LEED) – United States;
   - Green Star – Australia;
   - Building Research Establishment Environmental Assessment Method (BREEAM) – UK;
   - China's Three Star Evaluation Standard for Green Building – China;
   - Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) – Japan;

B. South Africa available practice:
   - Green Star SA Rating System

2.4.2 Recommendation and Comments

Different practices shall be used subject to the local context.

3POET Framework for Maintenance

3.1Maintenance technology

3.1.1 Maintenance activities categories

A. International available technologies (Howard, 2006):
   - Emergency maintenance: Such maintenances take place as needs rise and urgent, e.g., restoring lost electricity power.
   - Corrective maintenance: Such maintenances take place as needs rise and they are unplanned, e.g., fix a broken window.
   - Preventive maintenance: Such maintenance aims at maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects. The preventive maintenances are planned.
   - Predictive maintenance: Such maintenance is based upon the actual condition of the equipment and a determination of when maintenance should be performed to minimize costs. New technology techniques such as ultrasound, infrared and vibration online testing make predictive maintenance a viable alternative in certain circumstances. However, for most equipment the complex metrics for making educated guesses (predictive) is provided by preventive maintenance programs.

- Proactive maintenance: Such maintenance suggests taking action before failure happens: anticipating possibilities and getting ahead of the game. It means an emphasis on preventive maintenance instead of corrective.

B. South Africa available technologies: same as international practice.

3.1.2 Maintenance planning

A. International available technologies (Wang, 2002): The typical maintenance policies are listed as following. Please note that the listed policies are only a small subset of available methods.
   - Age-dependent policy: A unit is always replaced at its age or failure, whichever occurs first.
   - Periodic PM policy: In the periodic PM policy, a unit is preventively maintained at fixed time intervals that are independent of the failure history of the unit, and repaired at intervening failures.
   - Failure limit policy: PM is performed only when the failure rate or other reliability indices of a unit reach a predetermined level and intervening failures are corrected by repairs.
   - Sequential PM policy: Similar to the periodic PM policy but a unit is preventively maintained at unequal time intervals.
   - Repair limit policy: When a unit fails, the repair cost is estimated and repair is undertaken if the estimated cost is less than a predetermined limit; otherwise, the unit is replaced.

B. South Africa available technologies: The maintenance planning is interpreted to be a control system (Wang and Xia, 2015). According to the M&V principles (Xia and Zhang, 2013), a failed retrofitted item contribute degraded or zero energy saving to the aggregate savings. The maintenance actions can restore the energy saving of a failed item. Therefore, the aggregate energy savings over a specific time period are introduced as one of the objectives of maintenance planning in a retrofitting context. In this way, the maintenance is connected to the building energy efficient retrofitting and the long-term aggregate dynamics of the building energy efficiency is modelled.

3.1.3 Recommendation and Comments

Different technologies shall be used subject to the requirement of equipment.

3.2 Maintenance evaluation

A. International available practice:
   - The count of failure during a constant horizon;
   - The overall maintenance down time;
   - Maintenance costs;

B. South Africa practice: same as international practice.

3.3 Recommendation

International practices shall be used.

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