Learning about sustainability and green construction principles from pilot houses in Zambia

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Abstract: *The Zambia Green Jobs Programme (ZGJP) is a sustainable development programme which facilitates private sector development for inclusive green growth and decent green jobs, especially for women and young people. The focus is not just on the building technology or solution but the use of scalable demonstrations to (1) promote the change in mind-sets, skills, attitudes and behaviour on sustainable construction; and (2) develop markets for green construction by sharing the risk for innovation and product development with private investors and developers. This paper presents the methodology and results of the ZGJP demonstration house project. Three houses were pre-designed in an architectural competition in 2014 and the winning solutions were selected for the pilot phase (2015-2016) at the North Western Province in Zambia. The sustainability aspects in the pilot phase included design aspects (e.g. flexibility in space design, passive solar prevention, daylighting, natural ventilation), technology solutions (solar PV, window technology, energy efficient lighting, local materials), quality aspects in building phase (supervision, material testing) and capacity building issues (business for local contractors, job creation for locals, improved construction practises, contractual practises). The sustainability of the houses was evaluated based on review of the plans, interviews of the stakeholders and on-site visit including 'walk-through' evaluation using the Sustainable*

Building Assessment Tool (SBAT). The first users are moving in the houses before the end of 2016 and user responses will be available after that. The multi-step approach ending up to real houses with real habitants will give valuable feedback for the future design, green technology selections and construction process. The paper presents the project and critically evaluates the process and the final product. The review will be distilled into recommendations for the next phase sustainable green houses, which can be replicated to fill the huge gap in housing needs in Zambia.
Keywords: assessment, capacity building, green construction, sustainability

1. INTRODUCTION

The scale of the housing challenge in Zambia is immense, with a new dwelling required every two minutes of the working day until 2030 to meet urban housing demand (UN-Habitat, 2012). In addition to new housing provision, there is huge need to upgrade existing informal settlements and improve the access to land, as well as to develop a new national housing policy that reflects the need for housing provision which is affordable to the majority. It is obvious that the huge development in the housing sector is needed and this should be done according to green and sustainable principles keeping in mind basic principles of climate change mitigation and adaptation.

The Zambia Green Jobs Programme (ZGJP, 2015) is a sustainable development programme, funded by the Government of Finland and implemented by the Government of Zambia with technical assistance from the United Nations System led by the International Labour of Organization (ILO). The Programme facilitates private sector development for inclusive green growth that creates decent green jobs, especially for women and young people. This is achieved through the promotion of access to finance and business development business development services form micro, small and medium enterprises (MSMEs), as well as changing consumer buyer behaviour to develop green construction markets by sharing the risk of innovation, product development and investment with private developers and investors of sustainable and affordable green housing. The Zambia Green Jobs Programme shares the financial and technical risk of transformative and scalable demonstrations of green building solutions which encompass sustainable construction; water efficiency; clean and renewable energy; as well as integrated waste management. Together with the Copperbelt University, the Programme is also building the capacity of local architects on sustainable or green architecture. This paper presents the methodology and results of the ZGJP demonstration house projects with Barrick Gold Lumwana Mine as well as First Quantum Kalumbira Mine in the North Western Province of Zambia.

Piloting and demonstrations have been recognised to be a good way to show examples when opening the path for new products, ideas and business. Demonstration projects raise public awareness and send a strong signal to the private sector that investing in green growth infrastructure and technologies is feasible (AfDB-OECD, 2013). As part of ZGJP co-operation, Lafarge has started demonstration house projects at Lusaka and Ndola as showcase aiming at 600 affordable and environmentally friendly housing units for middle income families (Lafarge, 2015).

Pilot housing was assessed in terms of sustainability. The assessment aimed to establish the benefits of the approach developed for the pilot housing projects and identify opportunities for improved performance in future projects. It also aimed to capture learning which can be used to contribute to the wider Green Jobs Programme (UNDP, 2013).

2. RESEARCH METHODOLOGY

The concept of localisation and implementation of green sustainable building principles included several steps (Figure 1). In the first phase the architectural competition was arranged to get the local proposals for the green solutions. The winning solutions were selected for implementation phase based on pre-defined criteria. The architect finalised the drawings and local contractors were asked to give offers for the constructing the houses. The tenders were evaluated and compared to model house Bill of Quantities (BoQs) given by quantity surveyor. The Zambian contract models were used in making the contracts between project management and local contractors. The progress of the works was followed by regular site meetings and under supervision by clerk of works. The quality aspects of the construction works were supported by task lists of clerk of works and communication with contractors. During the finalisation phase of the houses the sustainability evaluation was done using SBAT methodology. The experiences during the planning, construction and evaluation phases gave the first feedback for future house concepts, and the final feedback will be got after the end users have lived in the houses for short period. The feedback can be used for improving the details in the model drawings. The optimal result would be realised with continuous running of the pilot house cycle (Figure 1), each cycle giving the better results than earlier ones.

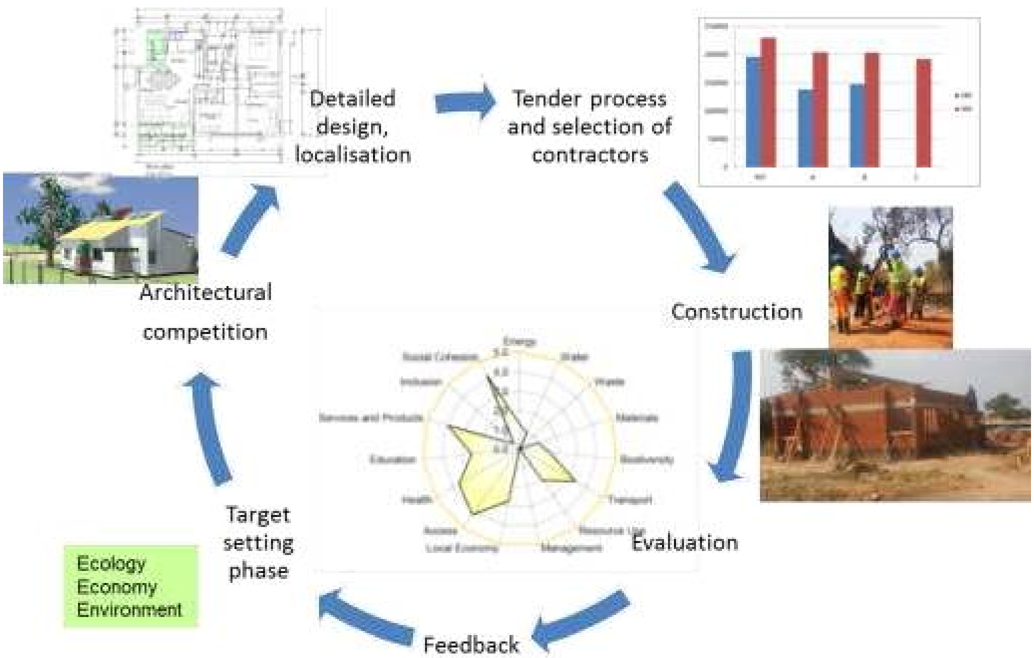


Figure 1: The phases of the pilot project.

2.1. Architectural competition

The Zambia Institute of Architects (ZIA) was mandated to run the design competition on behalf of the ILO and VTT Technical Research Centre of Finland (ILO News, 2013). The competition was open to all registered and student architects. The mandate was to design low cost and medium cost houses using appropriate technology and with utilization of local and sustainable materials, leading to improved eco-efficiency of future housing. The competition looked at the aspects of innovation concept, ecology and positioning of the building site, ecology of the construction phase, building concept itself, ecological building materials, energy savings and use of renewable energy and water solutions.

As a result three winners emerged from the two categories of the houses. The winners were evenly selected as it included both architects who had been practicing for a long time and those who were new as well as students. The result of the competition produced great innovations that were unique to the environment and the people. The competition exposed the participants to think widely and in an innovative way. All the winners came up with different solutions which exploited the recycling of existing materials to make building materials and aimed at reducing the materials that would have ended up at the dump site. Two types of the houses were selected for the following demonstration phase.

2.2. Construction process

The construction process includes several phases and tasks to perform. The path from the target setting phase to the use phase including service and maintenance is described in the figure 2. The target setting phase gave the basis for the pre-design in the architectural competition. The update of the plans was done in planning phase and tender process was performed based on detailed drawings. The evaluation of the offers including cost-benefit analysis lead to selection of the contractors, contract phase and practical construction works. The first performance evaluation of the houses was done based on SBAT methodology. The construction process included several supportive tasks improving the quality of works and materials e.g. planning the programme of works, delivery and storing of materials, protection of the materials on site, quality control actions, inspections, evaluations and valuation of the status of works. The practical works included capacity building for the workers and work safety education and implementation.

2.3. Sustainability assessment

Sustainability assessments were carried out on pilot housing. These aimed to capture the benefits of the approach and identify opportunities for improvement in future projects. The theoretical framework used for assessments was the Sustainable Building Assessment Tool (SBAT) Residential tool (Gibberd, 2005). The tool enables environmental, economic and social sustainability performance of housing to be measured and is based on the following criteria:

- Environmental Sustainability Performance: Energy, Water, Waste, Materials, Biodiversity
- Economic Sustainability Performance: Transport, Resource use, Management, Local economy, Services and products
- Social Sustainability Performance: Access, Health, Education, Inclusion, Social cohesion.

More detail on the SBAT and the assessment methodology is provided later in section 4.

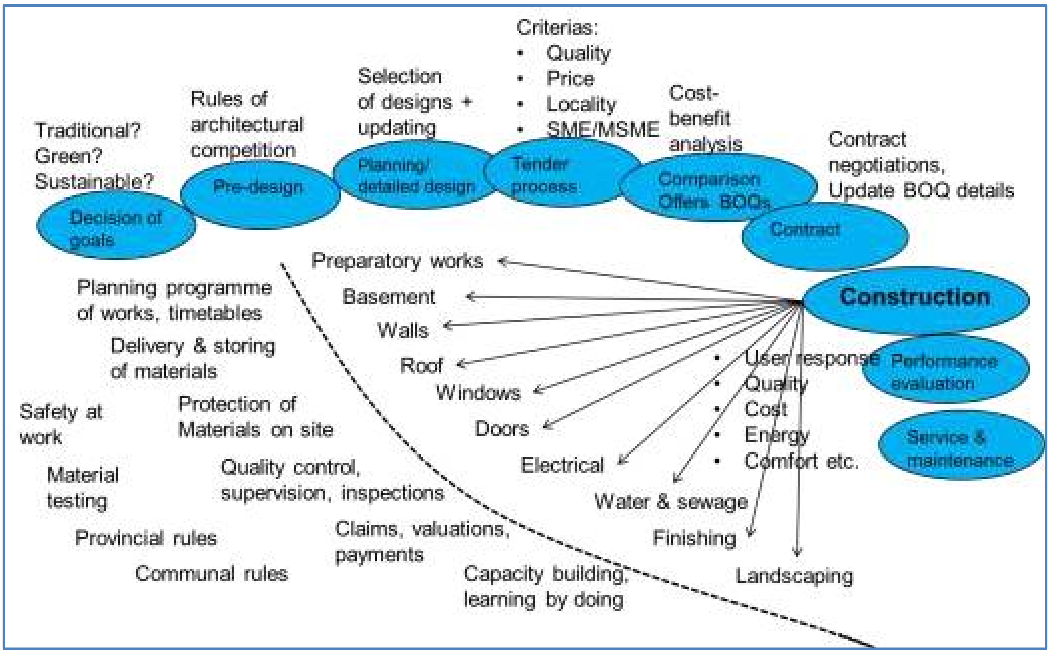


Figure 2: The phases and tasks in the pilot project.

3. PRINCIPLES OF GREEN CONSTRUCTION

The green, sustainability aspects in the pilot project included design aspects (e.g. flexibility in space design, passive solar prevention, daylighting, natural ventilation, water proof details), technology solutions (solar PV, solar thermal , window technology, energy efficient lighting, local materials), quality aspects in building phase (supervision methods and schemes, material testing) and social aspects including capacity building issues (business for local contractors, job creation for locals, improved construction practises, contractual practises), Figure 3. The holistic approach was limited in the pilot house case, because district level selections were not able to do, and the building plots were arranged by the local stakeholders without possibilities to optimise district level issues, e.g. waste handling and transportation issues.

The sections 3.1.-3.3. give a short summary of the design proposals in green sustainable houses. Most but not all of these options were implemented in pilot houses.

3.1. Design aspects

General design principles - The design was an open design to allow for easy flow of light and air. The room designs had no corridor space thus there was maximum utilization of the space.

Flexible solutions in walls /space modifications - The walls were made with thin walls to allow for easy removal and functional changes depending on client's needs. The design was an open design to allow for easy flow of light and air.

Daylighting strategies - The orientation of the buildings would be north and south to reduce direct sunlight entering the longer parts of the buildings early in the morning and late afternoon. The walls with windows would have recessed facades so that those rooms that receive a lot of sunlight will have sun shields. The internal middle walls have skylights to allow light in the middle of the house. The house will have a ceiling board that is made from recycled materials and the ceiling will follow the direction of the purlins so that the ceiling height is high enough to let hot air rise up and escape through the skylights.

Water proof issues – There will be no water splashing on the wall as there will be gutters to carry off the roof. The eaves of the house will be extended out by 1.2m so that there is no water that will splash on the walls. The plinth is high enough to avoid rainwater causing problems.

Material selections – Different aspects have to be taken into account in selection, e.g. fitness for use and local acceptance, use of local materials, minimised embodied energy, brick vs hydraform stabilised soil brick (SSB), steel roof vs tile roof and wooden vs metal window frames.

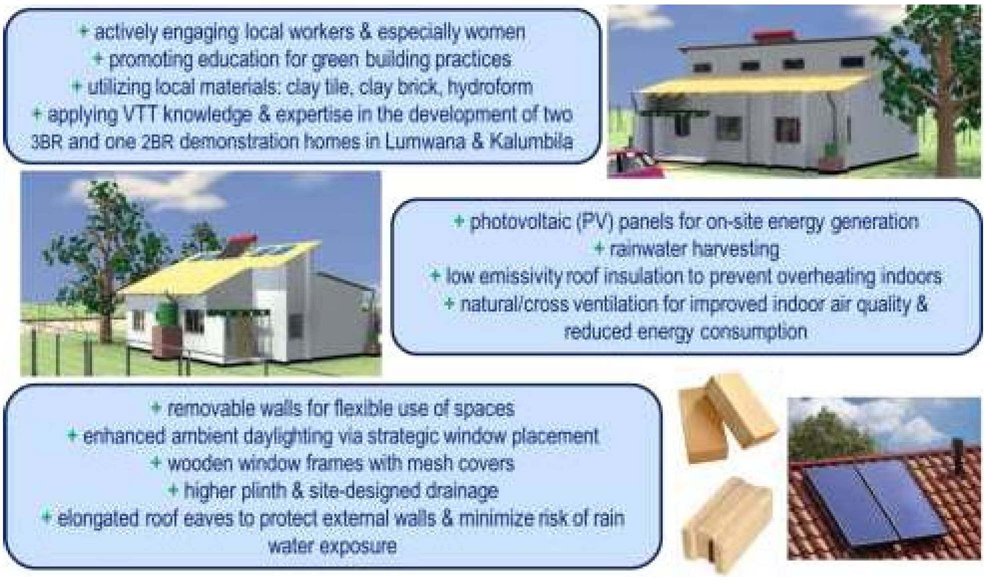


Figure 3: Green and sustainable principles in the demonstration houses.

3.2. House technologies

Solar PV - Three solar panels have been positioned on the western side of the house and the largest portion of the roof will be utilized with solar panels. The solar panels will be able to light the whole house and will be able to supply the sockets with sufficient energy.

Solar thermal – The domestic hot water will be produced with solar thermal collector combined with thermal storage tank.

Energy efficient lighting – The lighting fixtures will be selected to have low energy consumption light bulbs using less power than traditional ones.

Roof insulation / low emissivity coated membrane as underlay - The roof will have an underlay membrane that will act as an insulation from the heat of the roof transferring the heat to the rest of the building. The underlay will also protect the roof from leakages.

Ventilation - The rooms will have large windows on adjacent side of the rooms for cross ventilation and to capture the prevailing winds.

Rainwater harvesting - The design will use rain water and it is hoped that this will reduce the cost water by 30%. Water will be captured from the roof, from storm water drains and from the soil water. There will be two storage tanks on one end of the roof. These tanks are 200 litres.

Windows - The windows will be large and placed on adjacent side of the walls. The windows will allow cross ventilation and sufficient daylighting will enter each room. The areas where there is a lot light coming in through the windows will have both vertical and horizontal sun shades.

3.3. Social aspects in green construction

The holistic approach for sustainable green construction takes into account the social aspects including engagement of local workers (direct employment, selection of career based on showcase etc.), capacity building (skills development, education, training), local business opportunities and locality of the materials used in the construction. Engagement of local small and medium size enterprises is an important goal to offer decent jobs in green construction. The pilot house project was working closely with Zambian property developers and investors, architects and designers, and selected micro and small medium enterprises linked to construction project.

3.4. Quality assurance in construction

The quality assurance of the construction works have to be systematic and based on defined procedures. The tender process must be according to pre-defined procedure including requirements for quality of documents, e.g. bill of quantities (BoQ) must be comparable. Using of model BOQ would help and speed up remarkably the later phase valuation process. The agreement can be done based on nationally accepted model. The model agreement is profound and too heavy for small companies and one-cycle client, including 35 conditions and quite complex language. There is need of a short and simple contract model for residential houses and non-professionals as party in contract. As part of quality plan, the organisation and roles and responsibilities and communication plan should be given in written form. The clerk of works at site will safeguard the interest of the client on and around the site of project, and has a remarkable role in supervision of the quality of works. The checklist of tasks and responsibilities will help the systematic performing of actions.

Clear rules for health and safety at construction site are needed, and rules must be supervised. The practical instructions for workers are needed, e.g. agreement on shoes and hats to be worn on site during the construction work. The health and safety sessions/reviews should be held in site meetings regularly. Promoting safe, healthy and sustainable jobs in the building and construction sector is one aim of Zambian Green Jobs Programme (Mukosiku, 2014).

4. EVALUATION OF THE HOUSES

4.1. Methodology

The methodology followed for the assessing pilot housing involved the following tasks. Firstly, drawings, specifications, bills of quantities, product manuals, manufacturers' data sheets, reports and other documentation related to pilot housing were received and analysed. Secondly, visits to the sites were carried out and a visual inspection, field measurements and a photographic record developed. Thirdly, structured interviews were held with role players on the project including relevant built environment professionals. Fourthly, analysis and calculations were carried out on documentation, data captured on site and from interviews. Finally, data was inputted into the Sustainable Building Assessment Tool (SBAT) and performance reports generated. Further detail on the SBAT and a brief description of the assessment results are provided below.

4.2. The Sustainable Building Assessment Tool

The Sustainable Building Assessment Tool supports an integrated and responsive approach to achieving high sustainability performance in buildings. The tool is based on a holistic approach to addressing sustainability and includes social, economic and environmental criteria. SBAT criteria are based on a definition of sustainability found in the Living Planet Index (World Wild Life Fund, 2006). This defines sustainability as the achievement of minimum quality of life standards within the earth's carrying capacity. This is specifically defined as the attainment living standards above 0.8 on the Human Development Index (HDI) and the achievement of an ecological footprint (EF) of less than a 1.8 gha per person (gha, global hectare).

Therefore, the SBAT measures the performance of built environments in terms of its capability to support the achievement of living standards of above 0.8 on the Human Development Index (HDI) and an ecological footprint (EF) of less than a 1.8 gha per person. The assessment therefore provides an indicating of whether built environments have the required characteristics, and the configuration, to enable users (occupants) to live in a sustainable way.

The SBAT Residential tool and manual has a focus on built environments on residential environments, such as housing and apartments and their immediate neighbourhoods. The SBAT can be used to set targets for sustainability performance for buildings and their immediate neighbourhoods. It can also be used assess and validate the sustainability performance of buildings.

Scores in the Sustainability Building Assessment Tool range from 0 to 5. Performance can be related to the objectives of the SBAT (Introduction) and is indicated in Table 1.

Table 1. Key to SBAT scores (HDI=Human Development Index, EF=ecological footprint).

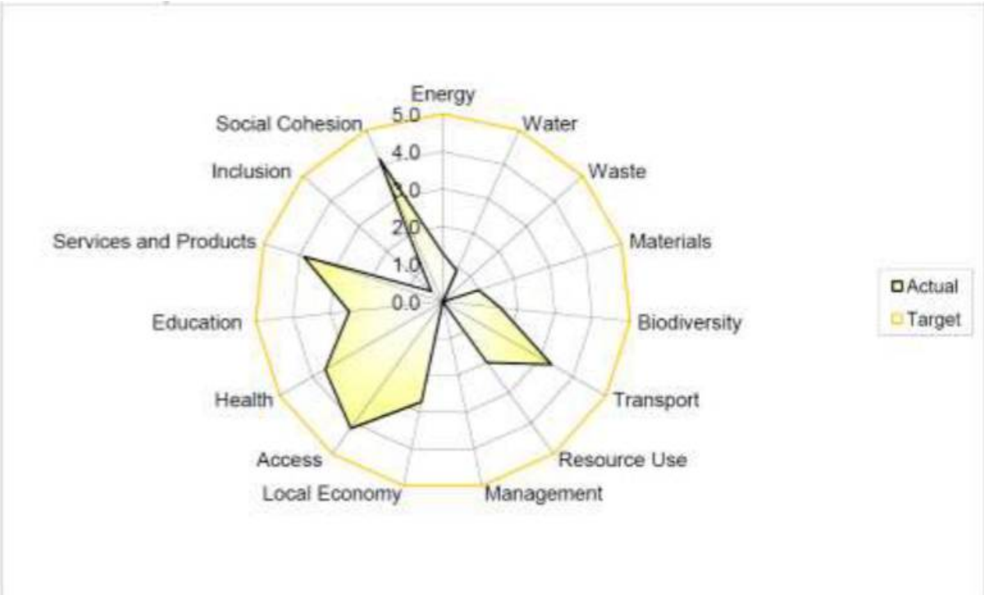
SBAT score	Sustainable built environment performance
5	Built environments provides **full** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
4 - 5	Built environments provides **excellent** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
3 - 4	Built environments provides **strong** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
2 - 3	Built environments provides **partial** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
1 - 2	Built environments provides **limited** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
0	Built environments provides **no** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.

4.3. Sustainable Building Assessment Tool Report and Findings

An extract of the SBAT report for pilot housing is provided in figure 4. This shows the performance of pilot housing in terms of SBAT criteria.

4.4. SBAT results

The SBAT report indicates that overall sustainability performance of pilot housing is 2.1. Reference to figure 1 indicates that there is **partial** *capability for occupants to achieve HDI and EF targets and live in a sustainable way*. This means that sustainability performance of housing is well above conventional housing. It also indicates that performance in different areas is mixed. The detailed nature of this performance can be ascertained by reviewing the spider diagram and the scores indicated in figure 4. The more detailed descriptions below indicate performance in the different areas and provide recommendations of measures that could be implemented to support improved performance.



SB4 Environmental, Social and Economic Performance	Score
Environmental	0.9
Economic	2.4
Social	2.9
SBAT Rating	2.1

Figure 4: SBAT Evaluation Report of Pilot Housing

4.4.1. Environmental performance

Environment performance of pilot housing is 0.9. This indicates that there is potential for improved performance. A review of the SBAT criteria indicates that performance could be improved in the following ways. Energy efficient equipment and renewable energy systems could be installed. Water efficient fittings and a rainwater harvesting could be incorporated. In addition, provision for recycling would also improve performance. Performance within biodiversity could also be improved through provision of ecological landscaping and food gardens.

4.4.2. Social performance

Social performance of pilot housing is 2.4. This indicates that performance in this area is better than environmental performance but that there is potential improvement. It shows that, in general, housing has good access to health, education and recreational facilities which support sustainable living patterns. However, provision for more inclusive environments could be addressed. This includes more accessible paths to housing as well as ensuring that circulation, spatial configuration and equipment within the house can be readily used by all occupants, including people with disabilities.

4.4.3. Economic performance

Economic performance of pilot housing is 2.9. This is the best performing area and indicates that construction of housing is supportive of local economic development. It indicates that construction of pilot housing has been carried out by local contractors in a labour intensive way. It also shows that housing is located in areas where there is good access to goods and services that support sustainability, such as access to local produce markets. However, aspects that could be addressed include metering for electricity and water consumption as well as the provision of building operation guidance to support sustainable occupation of housing.

5. FEEDBACK AND LESSONS LEARNED

The feedback from the stakeholders who have visited the demo houses has been very positive. Some development proposals for house designs have been given, e.g. adding of veranda roofs, decrease of the height of the building, lightening some internal walls and small changes for dimensions in toilet and bathroom, and these proposals have been communicated to the architect. During the construction phase some work phases had needs for development, e.g. work instructions for installation of underlay and window frame installations. The success and risk factors based on pilot house project experiences are listed in Table 2.

The implementation of the green sustainable principles in demonstration houses requires knowledge in design principles and availability of the technology solutions. The most of the construction techniques and installations on site belong to normal construction and there should not be any barriers for implementation. Some work phases require high expertise, e.g. installation of PV-system with other electricity system. The big concern is related to service and maintenance of the houses, which requires instructions and responsible person to take care of it.

The sustainability evaluation with SBAT method indicates that overall sustainability performance of pilot housing is 2.1, which means that there is partial capability for occupants to achieve HDI and EF targets and live in a sustainable way. The sustainability performance of housing is well above conventional housing. The best performing area is *economic performance* (2.9) indicating that construction of housing is supportive of local economic development. The construction of pilot housing has been carried out by local contractors in a labour intensive way. Social performance (2.4) indicates that housing has good access to health, education and recreational facilities which support sustainable living patterns, and there is potential for improvement. Environment performance (0.9) needs improvements, e.g.

energy efficient equipment and renewable energy systems should be installed and water efficient fittings and a rainwater harvesting could be incorporated.

Table 2. The success and risk factors based on pilot house project experiences.

Success factors	*Risk factors*
+ Preceding architectural competition for green sustainable houses gave a good basis for the project + Suitable models for Bill of Quantities (BoQ) + Active participation of the local stakeholders in the pilot project, including local consults for Operating Agent + Active support by local ILO office and participation in site meetings and site visits + Interest of local SMEs on construction business + Interest of building sector on dissemination workshops + Enthusiastic and motivated clerk of works + Systematic evaluation of progress and payment claims with help of local experts (quantity surveyor and clerk of works) + Fluent communication possibilities, e.g. by Whatsapp, supporting delivery of photographs and instant advices + existing instructions for different phases of construction works	- Complex land ownership issues and finding the proper model for land use in case of pilot houses - Poor knowledge on contractual issues, lack of contract model suitable for small residential houses - Lack of liquidity of local contractors – this may cause delays in material delivery and works - Disability of local contractors to give bank guarantees helping the payment processes - Lack of timetable discipline by contractors – this may be partly due to material delivery problems, but can be avoided by better work timetable planning - Capacity building needed for special topics in construction - Poor quality procedures and supervision procedures; there is need of written instructions - Risk of project costs increasing due to big variations in exchange rates and uncertainty in economy - Too high cost for management and supervision of works (clerk of works, quantity surveyor, architect) - Lot of good procedures and principles have been implemented in practise in pilot house construction sites, but the result dissemination should be done more, to get better value for money.

A recommendation for future houses is that explicit sustainability targets should be set for projects at the outset. The SBAT framework can be used for this purpose. This will enable designers and contractors to respond to these requirements and is likely to lead to much higher performance.

6. CONCLUSIONS

The paper gives an example of green sustainable demonstration house built in Zambia. The sustainable principles in building design, technology selection and social aspects are presented. The demonstration project aims at showing an example, which can be scaled and replicated in new buildings. The success and risk factors for the demonstration project and first feedback for the demonstration houses are presented. The feedback from the stakeholders who have visited the demo houses has been very positive. Some recommendations for the changes in technical details have been give and communicated to the architect.

The houses were designed according to principles of green and sustainable construction. The design selections were qualitative and there was no detailed quantitative evaluation of the sustainability including material flow and energy consumption calculations. The sustainability evaluation with SBAT method indicates that overall sustainability performance of pilot housing is 2.1, which means that there is partial capability for occupants to achieve HDI and EF targets and live in a sustainable way. The sustainability performance of housing is well above conventional housing, and based on SBAT evaluation it was possible to give proposals how to improve the performance, e.g. by using energy efficient equipment, renewable energy systems and water efficient fittings.

The most notable achievement during the demonstration house project are (1) capacity building of local architects, small scale contractors and service providers which resulted in jobs and skills development; (2) development of curriculum and course on sustainable architecture which ensures sector sustainability in terms of skills for sustainable architecture; and commercially (3) the inclusion of green building principles, processes and practices into the architectural code of the Kalumbila Town which will, result in thousands of green homes and communities in North Western Province.

The first users are moving in the houses before the end of 2016 and user responses will be available after that. The multi-step approach ending up to real houses with real habitants will give valuable feedback for the future design, green technology selections and construction process.

7. ACKNOWLEDGEMENT

The work related to this paper has been done as part of Zambian Green Jobs Programme (ZGJP). The ZGJP is a partnership between the Government of Zambia, the United Nations (UN) and Government of Finland. The programme is led by the International Labour Organization (ILO) and is aimed at promoting more and better jobs for inclusive and green growth in sectors where goods and services can be produced with an environmental benefit.

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