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Energy efficient building integrated photovoltaic housing

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Summary

An energy efficient building integrated photovoltaic (EE BIPV) house has been built and is being monitored at the University of Fort Hare, Alice campus, South Africa. This is part of an initiative to implement energy efficiency measures and utilize renewable energies in the residential sector. Spearheaded by the Fort Hare Institute of Technology and WattMore Power Solutions cc, the project seeks to showcase renewable energy utilization to policy makers, stakeholders in the building sector and the general public. Photovoltaic panels integrated onto the roof of the house supply all the electrical energy of the house and solar water heaters supply the hot water to the house. Passive solar design concepts were used to ensure passive indoor heating and cooling using direct solar access and natural ventilation, respectively. The grid independent house has been occupied since March 2009 and its thermal efficiency for the winter period is above 75%. The 3.8 kW photovoltaic (PV) generator has produced 630kWh of electrical energy by end of June 2009, sufficient to power all the electrical devices in the house.

End-user area	Target Audience	Technical
<input checked="" type="checkbox"/> New buildings	<input checked="" type="checkbox"/> Citizens	<input checked="" type="checkbox"/> Energy efficiency
<input checked="" type="checkbox"/> Refurbishment of buildings	<input checked="" type="checkbox"/> Households	<input checked="" type="checkbox"/> Heating
<input checked="" type="checkbox"/> Financial instruments	<input checked="" type="checkbox"/> Property owners	<input checked="" type="checkbox"/> Cooling
<input checked="" type="checkbox"/> Industry	<input checked="" type="checkbox"/> Schools and universities	<input checked="" type="checkbox"/> Lighting
<input checked="" type="checkbox"/> Legal initiatives	<input checked="" type="checkbox"/> Decision makers	<input checked="" type="checkbox"/> Solar energy
<input checked="" type="checkbox"/> Planning issues	<input checked="" type="checkbox"/> Local/regional auth.	<input type="checkbox"/> Other
<input checked="" type="checkbox"/> Sustainable communities	<input type="checkbox"/> Transport companies	
<input checked="" type="checkbox"/> User behaviour	<input checked="" type="checkbox"/> Utilities	
<input checked="" type="checkbox"/> Education	<input checked="" type="checkbox"/> ESCOs	
<input type="checkbox"/> Other	<input checked="" type="checkbox"/> Architects/engineers	
	<input checked="" type="checkbox"/> Financial institutions	
	<input type="checkbox"/> Other	



Introduction

The residential sector consumes upwards of 17% electrical energy in South Africa. More than 80% of this is generated using fossil fuels that contribute immensely to environmental pollution and global warming. The use of energy efficient measures and renewable energy, complimenting fossil fuels can reduce electrical power outages during peak demand, and more importantly, cause a reduction of gaseous pollutants. The construction of the energy efficient building integrated photovoltaic (EEBIPV) house is an initiative of the Fort Hare institute of Technology and SMME, WattMore Power Solutions, and the house is located at the university of Fort Hare, Alice campus, Eastern Cape, South Africa.

Objectives

The energy efficient building integrated photovoltaic housing project aims at:

- demonstrating the application of renewable energy technologies;
- demonstrating the viability of passive solar, solar thermal and photovoltaics in the domestic built environment;
- training students and interested individuals in the fields of renewable energy and energy efficiency in the built environment;
- developing models on the performance of building integrated photovoltaic's;
- constructively influence energy and renewable energy policy;
- making a contribution towards a reduction in greenhouse gas emissions to address climate change issues;

Methodology

A whole building design approach was used before starting the construction of the house in September 2008. The design team discussed the integration of all building components and systems that work together to save energy and reduce environmental impact. Simulation software AutoCAD, ECOTECT, and PVdesignPro were used to optimise building thermal and electrical performance. The initial plan to have the house operational by November 2009 could not be achieved due to logistical and meteorological challenges. There were delays in delivery of building materials since suppliers are limited in the area. The processing of payments to suppliers using the university finance department was also time consuming. In some cases, special equipment such as the inverters and charge controllers for the photovoltaic system had to be imported. Notwithstanding these challenges, the EEBIPV house was completed in February and occupied in March 2009.

Photovoltaic modules were mounted on the north-facing roof in such a way that they replace conventional roofing material as shown in figure 1. The PV panels then act as a building envelop and also supply the electrical energy requirements of the house. The PV generator has a maximum capacity of 3.8kW, deemed sufficient to supply all the electrical energy requirements of the house. Furthermore, energy efficient devices are used in the house as way of reducing household demand.

Passive solar design of the house entails the use of the site climatic conditions and figuring the correct building orientation.



With large windows and clerestory windows (figure 2) located on the north facing side of the house, the lower winter sun is allowed to heat both the front and rear of the inside of the house.

Sufficient overhangs protect the windows from the high summer sun and when opened, the clerestory windows on northern roof enhance cooling through natural ventilation. The hot water requirements of the house are met by solar water collectors installed on the north-facing roof as indicated by figure 3. The rear side of the indoor roof was insulated using nansulate insulation coating to enhance temperature lag between in- and outdoor temperatures. The thermal and electrical performance of the house is being monitored by a data acquisition system. The choice of building components was influenced by the simulation results and the costs involved. Interestingly, most of the locally available materials such as bricks, cement, solar water heater were found sufficient. The project targets university students, the local community and policy makers so as to promote best practices in the built environment. A lot of interest was generated in the community when schools were invited to participate in the naming of the energy efficient house.

Financial resources and partners

The total cost of the basic solar energy house was R 215,000-00. This implies that the average building cost was R 2,687-50/m². This excludes contractor fees, design of the structure and pre-construction simulation. Key renewable energy interventions such as the PV system contribute about 40%, and the solar water heater 5% to the total cost of the building. Most passive solar house features are a matter of design with little or no costs involved. When rolled out on a massive scale, we expect the cost per unit to go down.

The major sources of funding were Eskom, South African Energy Research Institute (SANERI), DTi through THRIP, UFH and Denver Hornsby. Various in-kind materials and services were also received.

Finding / Outcomes

During the first five months of operation (February to June 2009) the photovoltaic generator has supplied 630kWh of electrical energy to the battery bank (408Ah, 48V) and household appliances. The average yield in this period was 1.02kWh/day/kW_p corresponding to a yield of about 372kWh/year/kW_p. The daily household demand averages 0.149kW and is fully met by the PV system. Since the house is independent of utility grid, the daily electrical energy supply equates the minimum daily energy saved.

Figure 4 lists for the month of June 2009, the actual energy produced (regulated) by the PV generator, the amount it would have cost for this energy (at R 0-74/kWh), the energy that could have been produced (unregulated) as well as the corresponding cost as calculated with the proposed R 4-49/kWh value for the Renewable Energy Feed-in Tariff. The net income (avoided cost plus feed-in rebate) is R 1,524-88. This amount is very attractive and reduces the payback period of the solar house significantly.



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A further advantage is that the design and technologies used can be replicated anywhere in South Africa and should in particular be considered, at a smaller scale for low-cost housing.

The total expected annual energy produced by the PV generator should result in a 5.3 tonne CO₂ mitigation. The figure also shows the daily income over June. The indoor heating and cooling and hot water demand met by solar energy is not factored in these values.

Figure 5 shows the average daily temperature profile in and outside the house. The thermal efficiency for June was found to be 75% implying that for 75% of the month there was no need to heat or cool the house. This of course reduces the electricity consumption even further.

To create awareness of renewable energy, energy efficiency and their applications, local schools were invited to name the completed house shown in figure 6. Alice Primer received the award of four energy efficient computers by submitting the name 'LangalinaMandla' meaning powered by the sun. Students and pupil's participating in the annual National Science week programme are also set to visit and tour the energy efficient house on the 4th of August 2009.

Other benefits

Local labour was used during the construction of the house. During the busiest period in December 2009, up to 12 personnel were working on the house at the same time. In total, 25% of the building cost was for paying builders, plumbers, the electrician and general workers.

Lessons learned and repeatability

Designing and constructing an energy efficient solar home is a challenge. The houses usually cost more and take longer to build than conventional houses especially if the contractor is not familiar with green building construction techniques and products. Even though the house structure may differ slightly from conventional houses, builders and contractors appeared unwilling to deviate from usual practice. We found that additional training for local builders, solar water heater installers (plumbers) and carpenters who fitted the solar panels to the northern roof might be required.

It is important to evaluate the design plan, building costs, ease of construction, limitations of builder and compliance with local building codes before beginning construction to avoid unnecessary delays later. The choice of builder is important. An experienced and reputable builder with proper references should be used. It is also necessary to have a builder with a proper office with a landline (cell phone office is not encouraged) and a valid licence from the state building council. More importantly, a contract with deliverables and timelines should be signed and each have own copy. It was found prudent to choose building materials that are produced locally and that, therefore consume less energy to transport.

Some building plans are relatively simple and inexpensive while others are complex and, thus expensive. Our contractor never considered the complexity of the north facing roof structure but charged according to the building total floor area.



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At roof level, an expert carpenter had to be hired to lay the roof truss network needed to support the photovoltaic panels. Similarly, the electrician was not familiar with the photovoltaic generator wiring. Changes to house design need to be discussed and forwarded to the builder in time. The supplied solar panels had different dimensions compared to the design panels and this caused delays while we altered the northern roof truss spacing. The estimated date of completion was affected by design alterations and this led to additional building costs. The payment of subcontracted work to the skilled workmen hired at roof stage needed to be discussed at the start of the project.

Payment in full at the beginning of project should be avoided if possible. Progressive payments of a portion of the total amount at each building stage give more control over the project. We also learnt that safety issues take precedent over all other issues. The “it won’t happen to me attitude” has to be discouraged all the time so as to minimise construction accidents.

The major lessons learnt are that the building needs to be designed, and its thermal and electrical performance optimised before construction begins. A green building owner needs to procure the building materials in time to avoid delays and the choice of the contractor is as important as the design itself. Nothing beats proper construction technique and attention to detail.

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Printed reports or other literature available:

Title:

Cost: #if applicable#

Other contacts: #please only give full contact details (name, address, email, telephone) if you have confirmed that they are willing to respond to enquiries. These could for example be: host organisation, equipment manufacturers, financial organisations, etc.#



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Figure 1: Integrated Roof.



Figure 2: Clerestory Windows.



Figure 3: Solar water collectors.



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PV supply regulated	Grid Cost Avoided	PV supply unregulated	Available for feed-in	Feed-in Rebate	Net Income
123 kWh	R 90.72	442 kWh	319 kWh	R 1,434.17	R 1,524.88

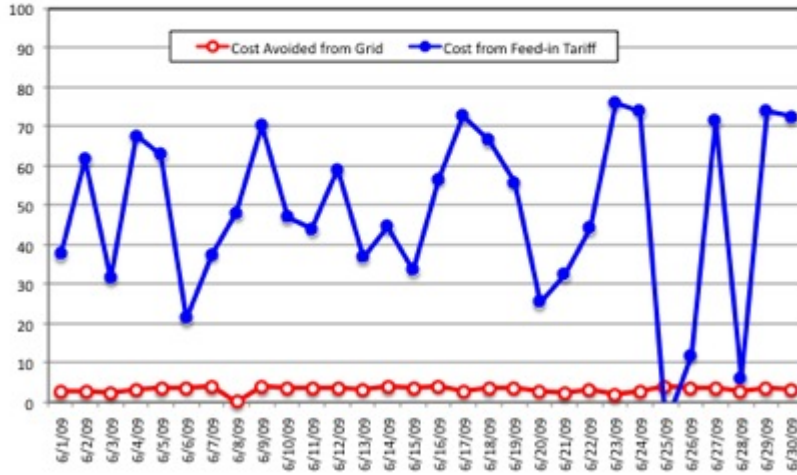


Figure 4: Cost Analysis EE BIPV House.

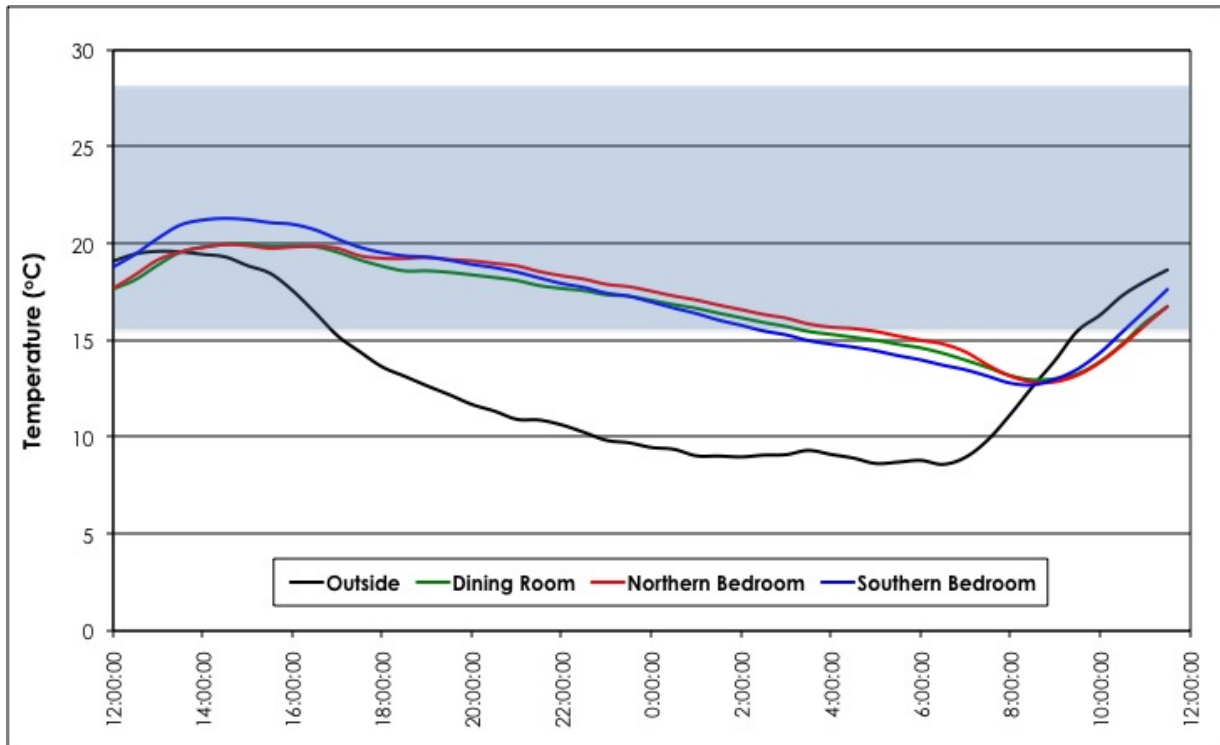


Figure 5: Thermal Efficiency.



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Figure 6: EE BIPV House, Langalinamandla.