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Integrated sustainable roof design

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Abstract

'Necessity is the mother of invention'…this proverb is very true with all great inventions that contribute to sustainable development. High density and steep land value have driven people to maximise liveable and productive spaces in urban settings. This include the reinvention of roofs' functions extending from merely a protection from the elements to a platform housing sustainable building technologies such as green roof, rainwater harvesting and photovoltaic power generation. On one hand, researches or different sustainable technologies are competing for funding, resources, space and recognition. On the other hand, some of the green building rating criteria have immense influence on decision makers to choose only one between various sustainable building technologies. This paper explores the possibility of combining green roof, rain water harvest system and building integrated photovoltaic thermal power generation to explore integrated sustainable roof design (ISRD). Potential integration benefits including: i) The increase of roof ambient temperature due to the installation of building integrated photovoltaic thermal power generation can be offset by green roof. ii) The energy gained from building integrated photovoltaic thermal power generation can be utilised to operate irrigation system for green roof during draught season. iii) Polluted rainwater runoff can be cleaned via green roof and improve the quality of collected rainwater in rain water harvest system. iv) Harvested rain water can be utilised to irrigate green roof during hot weather. ISRD can be modified accordingly to suit specific needs. Researchers with different specialisations can work together to conduct research based on ISRD and to explore possibilities integrating other suitable sustainable technologies into ISRD.

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Keywords: green roof; rain water harvest system; building integrated photovoltaic thermal power generation; solar energy; integrated sustainable roof design; green building rating system; sustainable development

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1. Introduction

Present overwhelming demand in urban development has imposed a great pressure in property developers and designers to maximize the use of every square inch of a building space including roof area. As responding to this current spatial needs as well as to global environmental issues, the function of a roof is now days stretched from a mere protecting element from weather to a platform accommodating sustainable building technologies such as green roof, rainwater harvesting and solar energy collector.

1.1. Green Roof

As land become scarce and development is inevitable in meeting growing need of current population, green spaces has paved the solution in enhancing the value of development in any nation. One promising option is the greening of buildings [1] by implementing green roofs and green walls. This will increase the percentage of greenery in urban built-up area and bring back the vanishing urban green space [2]. The definition of green roof is the creation of 'contained' green space on top of a human–made structure, and in all cases the plants are not planted on the 'ground' [3]. There are two main types of green roofs distinguished in Europe: extensive and intensive [4] [5]. Extensive green roofs with a substrate layer with a maximum depth of about 150 mm, with usually Sedum species as the major part of the vegetation. Intensive green roofs with a substrate layer with a depth of more than 150 mm, and usually grasses, perennial herbs and shrubs make up the main constituents of the vegetation. Previous researches show that green roofs have numerous environmental benefits such as reduce flood risk, improve rainwater runoff quality, mitigate urban heat island, building energy saving and provide urban wildlife habitat.

1.2. Rain Water Harvest System

Rainwater harvesting or the collection and concentration of rainfall methods has been utilised for centuries to fulfil household and agriculture needs. The construction of water tanks in the courtyards of rural homes has solved the problem to haul water from distant source [6]. Rain water harvest system (RWHS) on domestic allotments has the potentials to be an important contributor to urban water self-sufficiency by mitigating the ongoing water supply crises experienced by many urban centres [7]. Literature review has shown that many countries including Singapore [8], Denmark [9] and Australia [10] are now managing and legislating collection of rainwater from roof tops. Rooftop collected rainwater is usually used for toilet flushing, laundry and garden irrigation and typically supplies 25% of the domestic drinking water use [11].

Roof materials, degree of slope and runoff coefficient (RC) are very important factors in assessing and determining the rainwater harvesting potential. The selection of sloping smooth roofs (roofs with a RC > 0.9) generally has potential approximately 50% greater than flat rough roofs (roofs with RC < 0.62). Roofs with steeper slope also have better rainwater harvesting potential [12].

1.3. Building Integrated Photovoltaic Thermal Power Generation

Considering that global energy usage and price has been increasing steadily throughout the years, switching to other sustainable and renewable energy sources such as solar energy could be a viable move [13]. Adoptions of the photovoltaic (PV) technology for electricity generation in the residential and commercial sectors have been evolving as a promising option for renewable energy supply [14]. Analysis has been carried out to study o the economical, environmental and technical aspects of the photovoltaic technology [15]. Historically, the stand alone photovoltaic (SAPV) has not been a cost-effective source of power generation, therefore the integration of photovoltaic and solar thermal collectors (PVT) [16] into the walls or roofing structure of a building which lead to building integrated photovoltaic thermal (BiPVT) could provide greater performance. One research shows that the energy and exergy efficiencies of the amorphous silicon BiPVT system are found to be 33.54% and 7.13% respectively under the composite climatic conditions prevailing at New Delhi and the cost of BiPVT power generation is approximately US $ 0.1009 per kWh which is much closer to that of the conventional grid power. [17].

1.4. Integration of Sustainable Building Technologies Issues

When researchers and the industry sectors often mentioned about integrations, doing it is another matter. Researches usually focus on very specialized area and generalizing other areas. Researches or sustainable technologies are competing for funding, resources, space and recognition. Without proper integrations, green roof, rain water harvest system and building integrated photovoltaic thermal power generation are going to different directions.

Green building rating systems are tools used to assess how "green" are the buildings. Some of the green building rating criteria have immense influence on decision makers to choose only one between various sustainable building technologies. A simple example is the allocation of scoring weight for building integrated photovoltaic thermal (BiPVT) power generation and green roof in LEED 2009 (New Construction And Major Renovations) [18] and Green Building Index Version 1.0 (Non-Residential New Construction) [19].

Table 1. LEED 2009 (New Construction And Major Renovations) Scoring Weight Comparison

LEED 2009 (New Construction And Major Renovations) Criteria	Maximum Score	Scoring Weight
<u>EA Credit 2: On-site Renewable Energy</u>		
Assess the project for non-polluting and renewable energy potential including solar energy	7	7 / 110
<u>SS Credit 7.2: Heat Island Effect—Roof</u>		
Install a vegetated roof that covers at least 50% of the roof area.	1	1 / 110

Table 2. Green Building Index Version 1.0 (Non-Residential New Construction) Scoring Weight Comparison

Green Building Index Version 1.0 (Non-Residential New Construction)	Maximum Score	Scoring Weight
<u>EE 4 Renewable Energy</u>		
Assess the project for renewable energy potential including solar energy	5	5 / 100
<u>SM 12 Greenery & Roof</u>		
Install a vegetated roof for at least 50% of the roof area.	1	1 / 100

Table 1 and 2 show that building integrated photovoltaic thermal (BiPVT) power generation have a much better chance to outplay green roof in green building rating systems "point chasing". Decision makers may try to maximise the roof area for solar energy gaining higher score in renewable energy criteria; leaving no or little space for green roof. Both the above rating system has indirectly encouraged the adaptation of BiPVT as compared to green roof.

2. Integrated Sustainable Roof Design

A new perspective is crucial when dealing with sustainable building technologies. Instead of creating negative competition between sustainable building technologies, researches and green building rating systems must explore and capture the potential benefits from the integrations.

This paper explores the possibility to combine green roof, rain water harvest system and building integrated photovoltaic thermal power generation to form integrated sustainable roof. The reason to explore integrated sustainable roof design (ISRD) demonstrated in Figure 1 is to stop viewing green roof, rain water harvest system (RWHS) and building integrated photovoltaic thermal (BiPVT) power generation as separate sustainable building solutions.

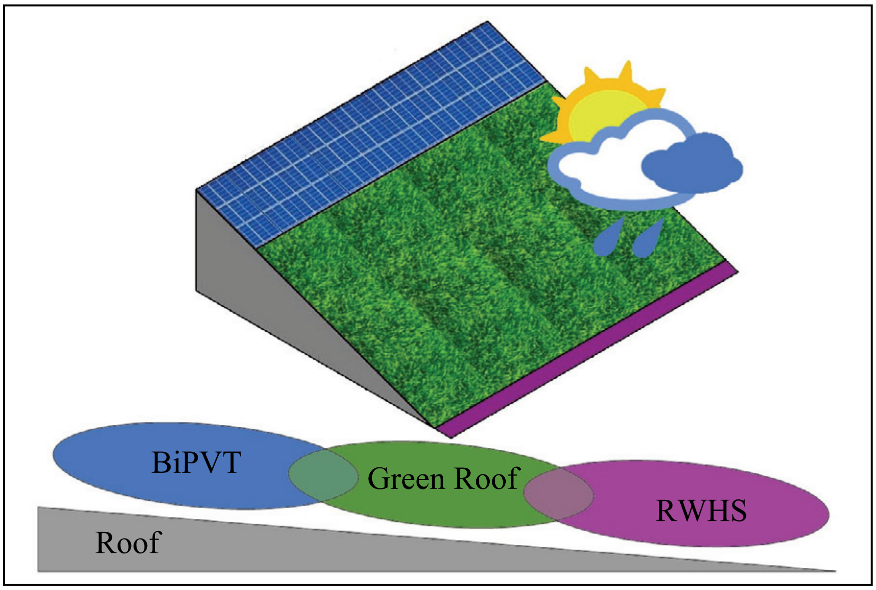

Fig. 1. General Layout of Integrated Sustainable Roof Design (ISRD)

Potential integration benefits in integrated sustainable roof design including:

i) The increase of roof ambient temperature due to the installation of building integrated photovoltaic thermal power generation can be offset by green roof.

ii) The energy gained from building integrated photovoltaic thermal power generation can be utilised to operate irrigation system for green roof during draught season.

iii) Polluted rainwater runoff can be cleaned via green roof and improve the quality of collected rainwater in rain water harvest system.

iv) The rainwater harvested from the rain water harvest system can be utilised to irrigate green roof during hot weather.

If all these different technologies are not viewed separately but as a single integrated design approach, then decision makers will not have to sacrifice one sustainable technology for another. Instead of conducting separated researches that focus on only one sustainable technology, researchers with different specialisations can now conduct collaborative researches based on integrated sustainable roof design (ISRD).

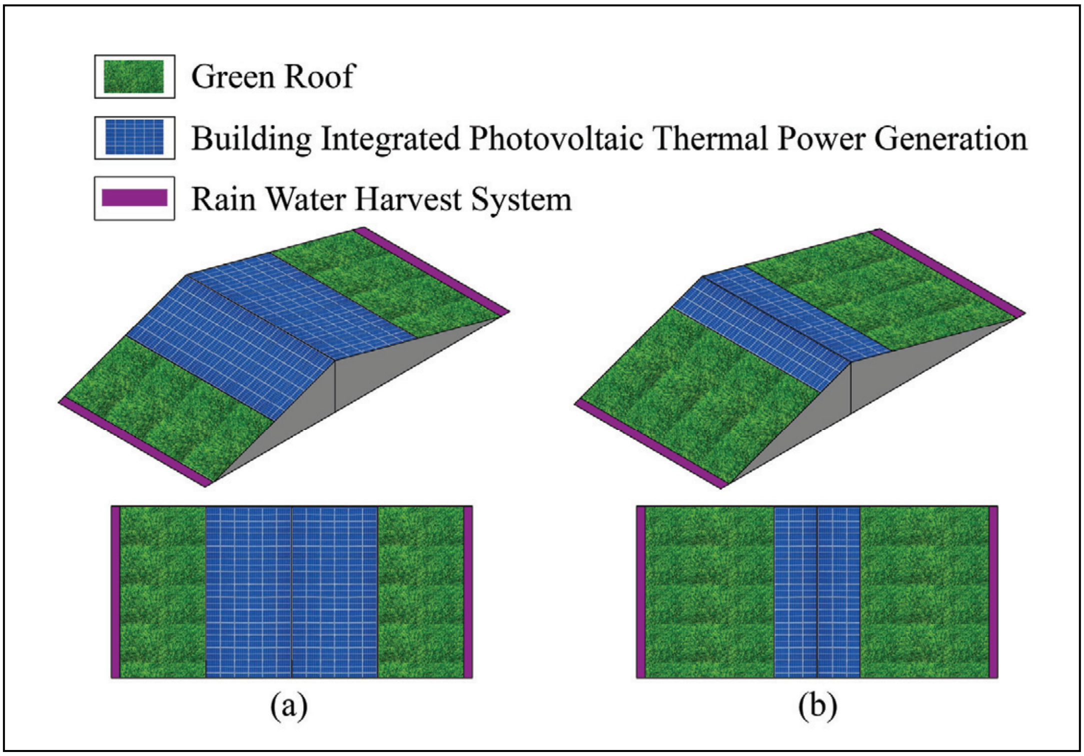

Fig. 2. (a) ISRD with 50% BiPVT, 50% green roof and RWHS (b) ISRD with 25% BiPVT, 75% green roof and RWHS

ISRD can be modified accordingly to suit specific needs in different situations. The modifications can take into consideration of the criticality and priority of sustainable development issues such as building energy saving, urban heat island, flood risk, polluted rainwater runoff, water supply and urban wildlife habitat.

Figure 2 (a) shows an ISRD with 50% roof area installed with BiPVT to cater high energy usage. This high BiPVT ratio ISRD type is suitable for rural area buildings where possible inconsistency and lack of energy supply are a major concern.

Figure 2 (b) shows an ISRD with 75% roof area installed with green roof to mitigate Urban Heat Island (UHI) and to provide urban wild life habitat. This high green roof ratio ISRD type is suitable for very crowded urban area where flash flood and lack of green space are major concerns.

A further understanding of how integrated sustainable roof design approach might be able to contribute to the environment must be clearly assessed and acknowledged in the green building rating systems. The assessment criteria and scoring systems must be able to capture most of the contributions of various sustainable technologies. For example the employment of green roof has benefit not well assessed in current rating systems such as reduction in thermal transmittance which will reduce the building initial building energy index (BEI).

3. Conclusions

The study suggests that BiPVT, green roof and rain water harvest system should be combined into integrated sustainable roof design (ISRD) as the integrations will provide numerous benefits. The benefits include the reduction of heat generated by BiPVT with green roof, power generated by BiPVT used to operate irrigation system for green roof, using green roof to clean rainwater runoff before going into rain water harvest system, and utilising stored rain water to irrigate green roof. The study also suggests that ISRD can be modified accordingly to suit specific needs in different situations depending on the priority on energy, green space or water demand.

Researchers with different specialisations must place better efforts to conduct collaborative researches based on ISRD, at the same time to explore possibilities integrating other suitable sustainable technologies into ISRD.

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