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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