Conceptual design of an integrated PV catchment storage system for rainwater harvesting

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Abstract. The issue of freshwater resources being continuously contaminated and polluted deemed to create water supply shortages. In urban areas where working population dominates, demands for freshwater supply increases rapidly over the years which lowers the government’s capability to supply and keeping in pace with the basic need in the near future. The RWHPV system are proposed to be located at the Faculty of Engineering Universiti Putra Malaysia PV in Serdang district which has a good rainfall collection throughout the year. The objective of this work is to feasibly identify and design a suitable rainwater catchment using PV array combinations, to calculate, design and install underground storage tanks with rainwater feasibility study and lastly to suggest the system as Clean Development Mechanism (CDM) for urban flood mitigation for public awareness and research purposes.

1. Introduction
Malaysia as a tropical climate country has enormously received 3,000 mm average/annum of rainfall, with an estimated 900 billion m$^3$ of water supply runoff dispersed into the river system \cite{1}. However, due to the increase in population, higher demand from industry and domestic/agriculture user, delay of treatment plant and most importantly lack of maintenance creates water crisis in urban area. The statement by Chief Minister of Selangor recently “Selangor will experience severe water supply issues due to higher demand and delay of the Langat 2 water treatment plant” \cite{2}, proves that preventive and realistic measures has to be table out in order to rectify the crisis.

Rainwater harvesting approach are generally define as a method for inducing, collecting, storing and conserving local surface runoff for agriculture production, domestic uses, and groundwater recharge \cite{3}, \cite{4}. The technique provides a cheaper and environmentally means for providing water resources at the same time reduce storm water discharges and urban floods. This practice was used throughout Asia, Africa and Middle East region (mostly in off-grid area) which serve as the main source of drinking supply \cite{5}, \cite{6}. Comprehensive review by Basinger et al. \cite{7} provides guideline for catchment area or storage tank capacity with a reliability factor based on water demand. The concept is further supported by urban environment improvement using green strategies \cite{8}, \cite{9}.

This work presents a conceptual approach for rainwater harvesting system using PV catchment concept with an underground water storage tanks. The objective of this research is to identify and design a suitable rainwater catchment using PV array combinations. To calculate, design and install...
underground storage tanks with rainwater feasibility study. Roof catchment area size and storage tank capacity typically are the main target system parameters for the rainwater harvesting.

2. Conceptual design and layout

Research collaboration between Universiti Putra Malaysia (UPM) and National Hydraulic Research Institute of Malaysia (NAHRIM) has been mutually bound to initiate the project showcase involving design and performance, installation and operational cost. The site plan for this project is approximately 1000 mtsq comprising green and wet area as shown in Figure 1.

![Figure 1](image1.png)

**Figure 1.** Site overview for PV Catchment mechanism and storm water retention basin

Common method used in the design of rainwater harvesting is the storage area of rainwater sub-surface called as cistern. Figure 2 illustrate the rainfall data for the nearest NAHRIM Weather Station and Figure 3 shows the location and conceptual layout of the system in Universiti Putra Malaysia.

![Figure 2](image2.png)

**Figure 2.** Rainfall trend based on nearest Weather Station. Data from [http://www.nahrim.gov.my/](http://www.nahrim.gov.my/)
Figure 3. Proposed overall layout for PV Catchment Mechanism at UPM site

A simple modification of PV skirting system, water storage and silicon bonding between each PV module as the method of catchment mechanism are shown in Figure 4.

Figure 4. Development of RWHPV using PV skirting, water storage and silicon bonding for collecting rainwater.

3, Result and discussion

The assessment are based on the Tangki NAHRIM software http://www.nahrim.gov.my/en/products/418-perisiantangkinahrim.html to determine and calculate the suitable size of tank depending on catchment area. The software provides some important parameter i.e Tank size (m³), Rainwater captured and Delivered (m³), Reliability (%), Coefficient of Rainwater...
Utilization (%), Storage Efficiency (%) and Time Tank Empty (%). The basic equation implied in the software for rainwater catchment system can be calculated using hydrological model as shown below

\[ Q = C \times I \times A, \]

Where: \( Q = \) Discharge m\(^3\)/time,  
\( C = \) Coefficient of Runoff (depends material used),  
\( I = \) Total annual rainfall in m,  
\( A = \) area of catchment in m\(^2\).

Table 1 shows the tank size (m\(^3\)) for the roof catchment area of 86 m\(^2\) and the runoff coefficient of 0.9. The water demand is estimated at 200 lt/day. The reference data are from Rainwater Station in Kajang, Selangor (Data: 1986 – 2006) and Sungai Balak, Selangor (Data: 2009 – 2016).

Table 1. Estimated 200 liter/day water demand in UPM for agricultural use (Rain Data: Kajang, Selangor).

| Tank Size (m\(^3\)) | Rainwater Captured (m\(^3\)) | Rainwater Delivered (m\(^3\)) | Reliability (%) | Coefficient of Rainwater Utilization (%) | Storage Efficiency (%) | Time Tank Empty (%) |
|---------------------|-------------------------------|-------------------------------|-----------------|----------------------------------------|------------------------|-------------------|
| 10                  | 3254.3                        | 1521.38                       | 99.24           | 46.75                                  | 47.40                  | 0.78              |
| 20                  | 3254.3                        | 1533.0                        | 100.00          | 47.11                                  | 47.74                  | 0.00              |
| 40                  | 3254.3                        | 1533.0                        | 100.00          | 47.11                                  | 47.74                  | 0.00              |
| 80                  | 3254.3                        | 1533.0                        | 100.00          | 47.11                                  | 47.74                  | 0.00              |

It is found that a 10 m\(^3\) rainwater tank can meet the water demand with reliability of 99.24% and increases to 100% reliability if 80 m\(^3\) tank size are used. Based on storage efficiency most of the tank size are similar with average 47.74% with the same capacity of rainwater captured. The appropriate design of storage tank can prevent overspill with regards to flooding. Oversize tank should also be avoided to reduce cost of construction where in this case, 20 m\(^3\) tank size are suggested for optimum capacity storage.

4. Conclusion
This works shares some conceptual approach for flood mitigation by means of rainwater harvesting using RWHPV system. The proposed model suggested a suitable tank size for rainwater storage using Tangki NAHRIM software with some limitation of Rainfall data. The cleaner production concept are reflected based on the Nexus Integration of Rainwater, Green Energy and Land resources.

Appendix
Supplementary data associated with this article can be found, in the online version, at http://www.nahrim.gov.my/en/products/418-perisiantangkinahrim.html

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