



Selected Rainwater Harvesting Technologies/Approaches

Project Raindrop

Date: July 2024

Location: Pakistan, The Netherlands

1. Introduction

1.1 Project Background

Water scarcity is a pressing issue in Pakistan, affecting both urban and rural areas, which poses a significant threat to sustainable development and human well-being. UNEP has initiated a project aimed to address this challenge by designing and implementing innovative rainwater harvesting technologies/approaches across Pakistan. This initiative, named Project Raindrop, aims to enhance water security and climate resilience through the implementation of efficient and scalable rainwater harvesting technologies.

1.2 Objective

The primary objective of this project is to develop a comprehensive blueprint for the implementation and scale-up of rainwater harvesting technologies/approaches tailored to the local-specific needs of Pakistan's communities. This blueprint will provide a detailed plan for the implementation of selected rainwater harvesting technologies that are sustainable, cost-effective, and adaptable to various environmental and socio-economic contexts.

1.3 Design Principles

In line with the project's goals, we have established a set of design principles to guide the selection and implementation of the most appropriate rainwater harvesting technologies/approaches. These principles ensure that the chosen technologies are environmentally sustainable, scalable, cost-effective, and inclusive. Key considerations include community involvement, resource efficiency, climate resilience, integration with clean energy solutions, regulatory compliance, ease of maintenance, and gender equality/inclusivity.

1.4 Technology Selection Process

To identify the most suitable rainwater harvesting technologies for this project, we conducted an evaluation of both traditional and innovative approaches. Our selection process was informed by the Terms of Reference (ToR) and guided by the design principles. We examined a wide range of technologies, assessing each against criteria such as sustainability, scalability, cost-effectiveness, and community involvement.

1.5 Selected Technologies

After a detailed analysis, we have selected two technologies that best align with our project's objectives and design principles. These technologies are new and have not yet been tested in real-life scenarios:

1. **Archi Slamdam with Smart Water Pump:** This innovative system combines an Archi Slamdam with a smart water pump connected to soil moisture sensors. It optimizes irrigation by activating the pump based on real-time soil moisture data, ensuring efficient water use and enhancing crop productivity. This technology is highly sustainable, scalable, and integrates clean energy solutions, making it ideal for diverse agricultural settings in Pakistan.
2. **5X5 Dam with Solar Panels:** This modular rainwater harvesting system includes a dam that collects rainwater and is equipped with solar panels to enhance water storage and supply. The 5X5 Dam is designed to be expandable and adaptable, meeting the water needs of various farm sizes and communities. It promotes resource efficiency and climate resilience while ensuring long-term water availability.

Alternatively, we have identified two existing rainwater harvesting technologies that could be effectively implemented based on their proven track records:

1. **Check Dams and Contour Bunds:** These structures are built across small streams or on sloping terrain to capture and store rainwater runoff. They help in reducing water flow velocity, promoting sedimentation, and enhancing groundwater recharge. Check dams and contour bunds are cost-effective, scalable, and involve significant community participation, making them suitable for various regions in Pakistan.
2. **Cisterns and Ferro-Cement Tanks:** These are robust storage systems designed to collect and store rainwater for domestic and agricultural use. Cisterns and ferro-cement tanks are known for their durability, cost-effectiveness, and ease of maintenance. They can be customized to different sizes and are capable of providing a reliable water source during dry periods.

Both sets of technologies are recommended solutions to address water scarcity and improve water management in Pakistan. The innovative new technologies offer the potential for cutting-edge solutions, while the existing technologies provide tried-and-tested methods.

2. Overview of Rainwater Harvesting Technologies

2.1 Enumerated Rainwater Harvesting Technologies

1. Rooftop Rainwater Harvesting (RTRWH)

- Widely used in India, Australia, Africa, and other regions.
- Captures rainwater from rooftops and stores it in tanks or reservoirs.

2. Surface Runoff Harvesting

- Practiced in India, Kenya, Australia, and Brazil.
- Captures and stores rainwater from surface runoff using check dams, farm ponds, and contour trenches.

3. Rain Gardens

- Common in the United States, Canada, Australia, and the United Kingdom.
- Utilizes gardens designed to capture and filter rainwater runoff.

4. Permeable Pavements

- Used in the United States, United Kingdom, Australia, and Germany.
- Allows rainwater to infiltrate through surfaces, reducing runoff.

5. Check Dams and Contour Bunds

- Implemented in India, Nepal, and Kenya.
- Structures built to slow down water flow and recharge groundwater.

6. Fog Harvesting

- Practiced in Chile, Peru, and Namibia.
- Captures moisture from fog using fog nets.

7. Subsurface Dams

- Used in Kenya, India, and Zimbabwe.
- Captures and stores rainwater underground.

8. Cisterns and Ferro-Cement Tanks

- Common in Greece, Caribbean Islands, and India.
- Used for storing rainwater for various purposes.

9. Floodwater Harvesting

- Implemented in Bangladesh, Pakistan, and Vietnam.
- Captures and stores floodwater for beneficial use.

2.2 Newly Designed Rainwater Harvesting Technologies

1. Archi Slamdam with Smart Water Pump

- Uses sensors to measure soil moisture and activate a pump to maintain optimal moisture levels.

2. Mobile Slamdam Emergency Unit

- Provides electricity and clean drinking water through a trailer equipped with water tanks and a drainage system to collect rainwater while driving.

3. Condensation Tube

- Uses a polycarbonate tube with a stainless steel spiral cooled by a pump to condense and collect water from the air.

4. 5X5 Dam with Solar Panels

- A modular dam that collects rainwater and uses solar panels to enhance water storage and supply.

5. HydroBag

- A modular system that uses excess solar power to heat water, providing a sustainable heating solution and water storage.

3. Scoring Matrix for Selecting Best Technologies

The scoring matrix will use the following design principles and criteria based on the Terms of Reference (ToR):

1. **Sustainability**
2. **Scalability**
3. **Cost-Effectiveness**
4. **Community Involvement**
5. **Resource Efficiency**
6. **Climate Resilience**
7. **Integration with Clean Energy**
8. **Regulatory Compliance**
9. **Maintenance and Operability**
10. **Monitoring and Evaluation**
11. **Gender Equality and Inclusivity**

Each criterion will be scored on a scale of 1 to 5 (1 = Poor, 5 = Excellent). See outcome in Table 1.

Table 1: Outcome Scoring Matrix Selection Rainwater Harvesting Technology

Technology	Sustainability	Scalability	Cost-Effectiveness	Community Involvement	Resource Efficiency	Climate Resilience	Integration with Clean Energy	Regulatory Compliance	Maintenance & Operability	Monitoring & Evaluation	Gender Equality & Inclusivity	Total Score
1. Rooftop Rainwater Harvesting	5	4	4	5	4	4	4	5	4	4	5	48
2. Surface Runoff Harvesting	4	4	4	4	4	4	3	4	4	4	4	43
3. Rain Gardens	4	3	4	4	4	4	3	4	4	4	4	42
4. Permeable Pavements	4	3	3	3	4	4	3	4	4	4	3	39
5. Check Dams and Contour Bunds	5	4	4	4	4	5	3	5	4	4	4	46
6. Fog Harvesting	3	3	3	3	3	4	3	3	3	3	3	34
7. Subsurface Dams	4	4	4	4	4	4	3	4	4	4	4	43
8. Cisterns and Ferro-Cement Tanks	4	4	4	4	4	4	4	4	4	4	4	44
9. Floodwater Harvesting	4	3	3	3	4	4	3	4	4	4	3	39
10. Archi Slamdam with Smart Water Pump	5	5	4	4	5	5	5	5	4	4	5	56
11. Mobile Slamdam Emergency Unit	4	5	4	4	4	5	5	5	4	4	5	54
12. Condensation Tube	4	4	3	3	4	4	4	4	3	4	4	41
13. 5X5 Dam with Solar Panels	5	5	4	4	5	5	5	5	4	4	5	56
14. HydroBag	5	4	4	4	5	5	5	5	4	4	5	55

4. Selected Technologies

The two technologies with the highest scoring are “newly designed technologies” viz. (1) Archi Slamdam with Smart Water Pump and (2) 5X5 Dam with Solar Panels. Despite that these two technologies have the highest scoring, they haven’t been tested in real life.

Alternatively, the two existing technologies with the highest scoring can be selected as part of the blueprint to scale up the rainwater harvesting technology across Pakistan based on proven technologies viz. (3) Check Dams and Contour Bunds and (4) Cisterns and Ferro-Cement Tanks.

Below is a detailed explanation of the selected technologies and why these have the highest scoring.

Newly designed technologies:

1. **Archi Slamdam with Smart Water Pump** (Score: 56) – See Annex 1
2. **5X5 Dam with Solar Panels** (Score: 56) – See Annex 1

Existing technologies:

3. **Check Dams and Contour Bunds** (Score: 46) – See Annex 1
4. **Cisterns and Ferro-Cement Tanks** (Score: 44) – See Annex 1

4.1 Archi Slamdam with Smart Water Pump

This technology integrates an Archi Slamdam with a smart water pump connected to soil moisture sensors. The pump activates based on soil moisture levels, ensuring optimal irrigation for crops.

Explanation scoring:

- **Sustainability (5):** The system efficiently uses rainwater for irrigation, promoting sustainable agricultural practices without depleting natural resources.
- **Scalability (5):** The technology can be easily scaled to different regions and adapted to various crop types and farming practices across Pakistan.
- **Cost-Effectiveness (4):** The implementation and maintenance costs are manageable, making it accessible for local farmers and communities.
- **Community Involvement (4):** Farmers and local communities are directly involved in the operation and maintenance of the system, ensuring it meets their specific needs and is culturally acceptable.
- **Resource Efficiency (5):** The technology maximizes water usage efficiency by only irrigating when necessary, reducing water wastage.
- **Climate Resilience (5):** The system is designed to adapt to varying rainfall patterns and climate conditions, making it resilient to climate change impacts.
- **Integration with Clean Energy (5):** The pump can be powered by solar energy, reducing reliance on non-renewable energy sources and enhancing sustainability.
- **Regulatory Compliance (5):** The design adheres to local and international regulations, ensuring safety, reliability, and legal compliance.
- **Maintenance & Operability (4):** The system is user-friendly and requires minimal technical expertise for operation and maintenance.
- **Monitoring & Evaluation (4):** The technology includes a monitoring system to track soil moisture levels and water usage, facilitating continuous improvement.

- **Gender Equality & Inclusivity (5):** The system ensures equal benefits for all community members, including women and youth, and involves them in operational activities.

4.2 5X5 Dam with Solar Panels

This modular dam collects rainwater and is equipped with solar panels to enhance water storage and supply. It is designed to be expandable and adaptable to different farm sizes and water requirements.

Explanation scoring:

- **Sustainability (5):** The dam promotes long-term water conservation and sustainable usage by capturing and storing rainwater for agricultural and domestic use.
- **Scalability (5):** The modular design allows for easy expansion and adaptation to different regions and varying population densities.
- **Cost-Effectiveness (4):** The technology is affordable, with manageable implementation and maintenance costs for local communities and government bodies.
- **Community Involvement (4):** The design and implementation involve local communities, ensuring that the system is tailored to their needs and is culturally acceptable.
- **Resource Efficiency (5):** The system maximizes water capture and storage efficiency, minimizing losses through evaporation and leakage.
- **Climate Resilience (5):** The dam is resilient to local climate conditions, including variability in rainfall and potential climate change impacts.
- **Integration with Clean Energy (5):** The solar panels integrated into the design enhance sustainability by providing a clean energy source for water pumping and other needs.
- **Regulatory Compliance (5):** The design complies with local, national, and international regulations, ensuring safety, reliability, and legal compliance.
- **Maintenance & Operability (4):** The system is easy to maintain and operate with minimal technical expertise, ensuring longevity and consistent performance.
- **Monitoring & Evaluation (4):** The technology includes a robust monitoring and evaluation framework to track performance and identify issues.
- **Gender Equality & Inclusivity (5):** The system ensures that vulnerable and marginalized groups, including women and youth, benefit equally and can participate in operational and maintenance activities.

Both technologies scored highest based on the design principles and the content of the ToR. They promote sustainable and efficient water management, are scalable and cost-effective, involve the community, integrate clean energy, and ensure compliance with regulations. Additionally, they are easy to maintain and operate, resilient to climate change, and inclusive of all community members. These factors make them the best choices for developing a blueprint for rainwater harvesting in Pakistan. However, these technologies haven't been tested in real-life.

4.3 Check Dams and Contour Bunds

Check dams and contour bunds are structures built across small streams or on sloping terrain to capture and store rainwater runoff. These structures slow down water flow, allowing it to percolate into the ground and recharge groundwater.

Explanation scoring:

- **Sustainability (5):** These structures promote long-term ecological balance by preventing soil erosion and enhancing groundwater recharge.
- **Scalability (4):** Check dams and contour bunds can be implemented in various regions with different topographies, making them adaptable and scalable across Pakistan.
- **Cost-Effectiveness (4):** Construction and maintenance costs are relatively low, making them accessible for rural communities and government programs.
- **Community Involvement (4):** Local communities are often involved in the construction and maintenance, ensuring the structures meet their needs and are culturally acceptable.
- **Resource Efficiency (4):** These structures efficiently capture and store rainwater, minimizing water loss and maximizing groundwater recharge.
- **Climate Resilience (5):** Check dams and contour bunds are resilient to climate variability, effectively managing runoff during heavy rains and droughts.
- **Integration with Clean Energy (3):** While they do not directly integrate clean energy, their passive nature ensures low energy requirements for maintenance.
- **Regulatory Compliance (5):** These structures comply with local and international regulations for water management and soil conservation.
- **Maintenance & Operability (4):** They require minimal technical expertise for construction and maintenance, making them sustainable for long-term use.
- **Monitoring & Evaluation (4):** Performance can be easily monitored through simple hydrological measurements and community feedback.
- **Gender Equality & Inclusivity (4):** Community-based approaches ensure that women and other vulnerable groups are involved in the construction and maintenance processes.

4.4 Cisterns and Ferro-Cement Tanks

Cisterns and ferro-cement tanks are structures used to store rainwater for domestic and agricultural use. They are made from ferro-cement, a composite material of cement, sand, and iron mesh.

Explanation scoring:

- **Sustainability (4):** These tanks provide a reliable and sustainable source of water, reducing dependence on groundwater and other sources.
- **Scalability (4):** The tanks can be scaled to different sizes and capacities, making them adaptable to various regions and needs.
- **Cost-Effectiveness (4):** Construction and maintenance costs are manageable, making them a feasible option for both rural and urban communities.
- **Community Involvement (4):** Local communities can be involved in the construction, ensuring the tanks meet their specific needs and are culturally acceptable.
- **Resource Efficiency (4):** These tanks efficiently store rainwater, minimizing losses through evaporation and leakage.
- **Climate Resilience (4):** The tanks provide a buffer against climate variability, ensuring a steady water supply during dry periods.
- **Integration with Clean Energy (4):** Solar-powered pumps can be integrated to extract water from the tanks, enhancing sustainability.
- **Regulatory Compliance (4):** The design and construction of these tanks comply with local and international regulations for water storage and safety.
- **Maintenance & Operability (4):** They are easy to maintain and operate with minimal technical expertise, ensuring long-term functionality.
- **Monitoring & Evaluation (4):** Performance can be monitored through simple water level measurements and community feedback.

- **Gender Equality & Inclusivity (4):** The tanks ensure equal access to water for all community members, including women and other vulnerable groups.

Both **Check Dams and Contour Bunds** and **Cisterns and Ferro-Cement Tanks** scored highly based on the design principles and the ToR. They promote sustainable water management, are scalable and cost-effective, involve the community, and are easy to maintain and operate. These technologies are also resilient to climate change and ensure compliance with regulations, making them the best choices for rainwater harvesting in Pakistan.

Annex 1

Selected Rainwater Harvesting Technologies

1. Archi Slamdam with Smart Water Pump

The idea of connecting an archi slamdam to a smart water pump. The pump can pump the slamdam empty.

This pump does not just do that, the pump is connected to a series of switches (relays). These relays can turn the pump on and off.

So when do you want the pump on?

That's simple: these turn on when an unfavourable moisture percentage in the soil is measured.

Using 3 to 4 sensors in the soil, the pump knows exactly when and how much moisture is needed.

The idea is that this will protect crops in Pakistan from drying out. Further, it increases the area where you can keep moisture-intensive crops in the country. Below is an overview with the average rainfall for each area, these vary enormously.

The following five crops are most commonly grown in Pakistan:

1. **Wheat (Wheat)**
2. **Rice**
3. **Sugarcane**
4. **Cotton (Cotton)**
5. **Maize (Maize)**

Here are the estimated amounts of water required by these crops per square metre:

1. **Wheat (Wheat)**
 - Water requirement: About 450-650 mm per growing cycle.
 - Converted: 45-65 litres per square metre.
2. **Rice (Rice)**
 - Water requirement: About 1,200-2,000 mm per growing cycle.
 - Converted: 120-200 litres per m².
3. **Sugarcane**
 - Water requirement: Approximately 1,500-2,500 mm per growing cycle.
 - Converted: 150-250 litres per m².
4. **Cotton (Cotton)**
 - Water requirement: About 700-1,300 mm per growing cycle.
 - Converted: 70-130 litres per m².
5. **Maize (Maize)**
 - Water requirement: About 500-800 mm per growing cycle.
 - Converted: 50-80 litres per sq m.

Rainfall per area

Karachi: 200 litres per m² per year

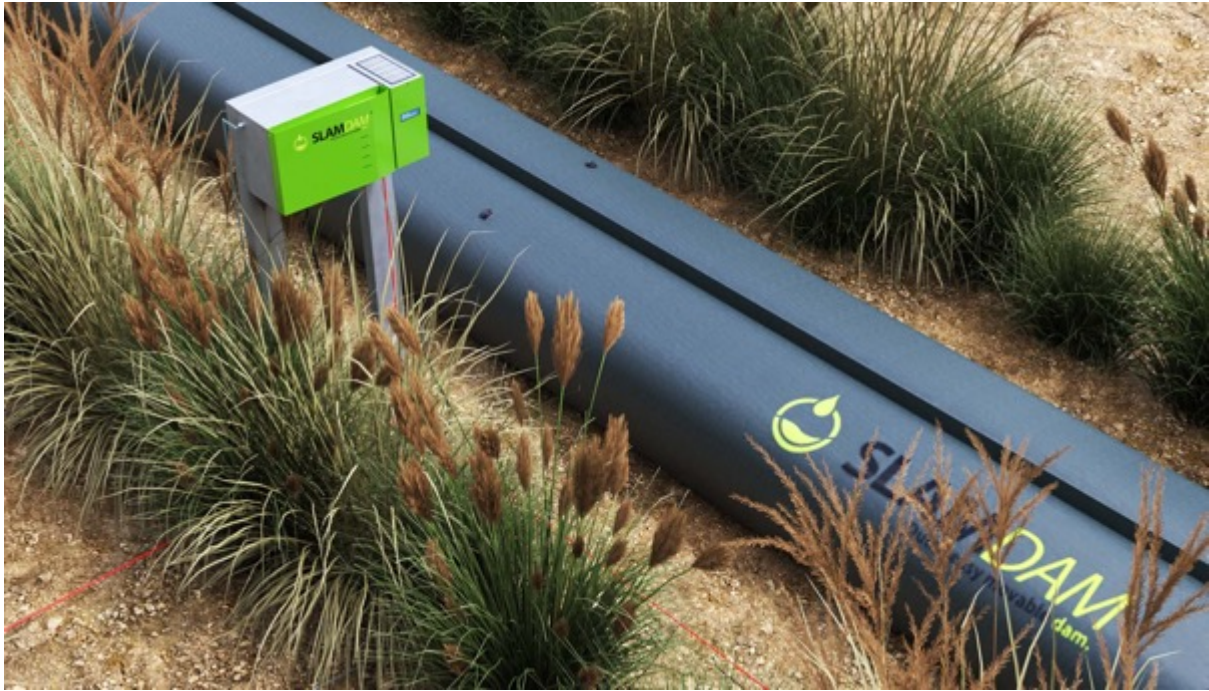
Lahore: 500 litres per m² per year

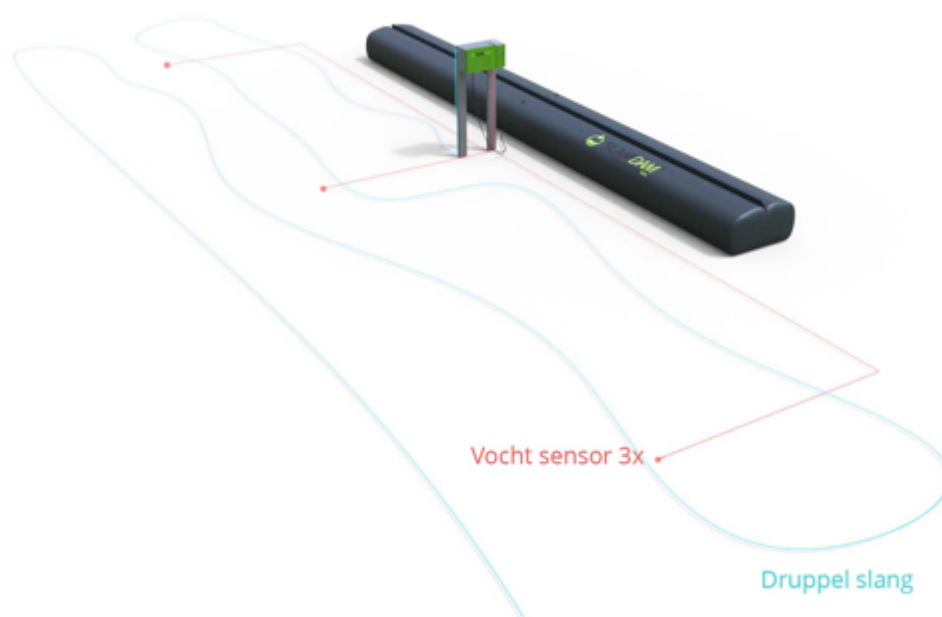
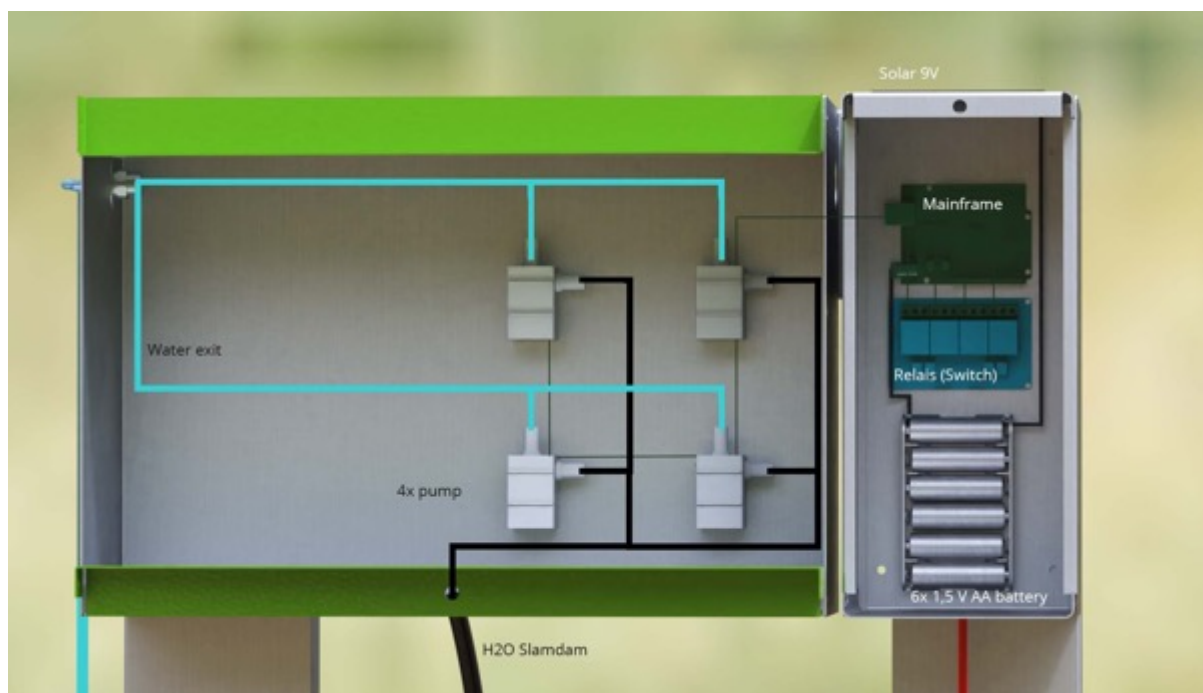
Islamabad: 1,000 litres per sq m per year

Quetta: 250 litres per m² per year

Peshawar: 400 litres per m² per year

Pictures





2. 5X5 Dam with Solar Panels

Every farm has a different format. At each farm, water consumption and electricity consumption is an issue.

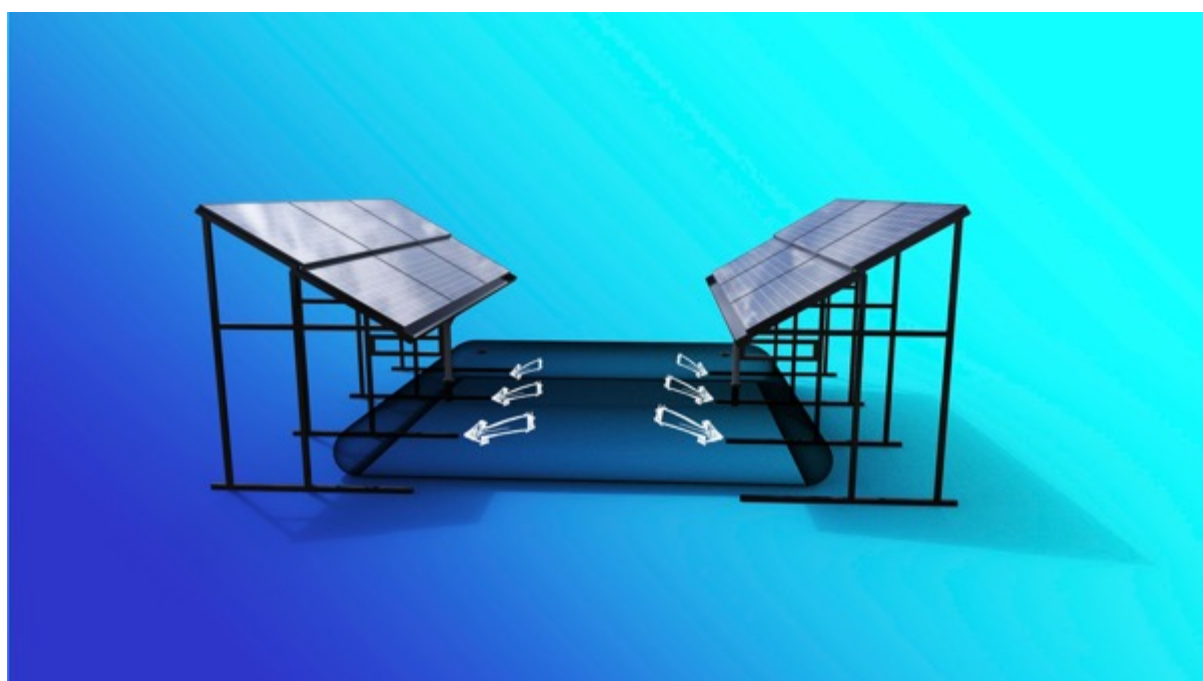
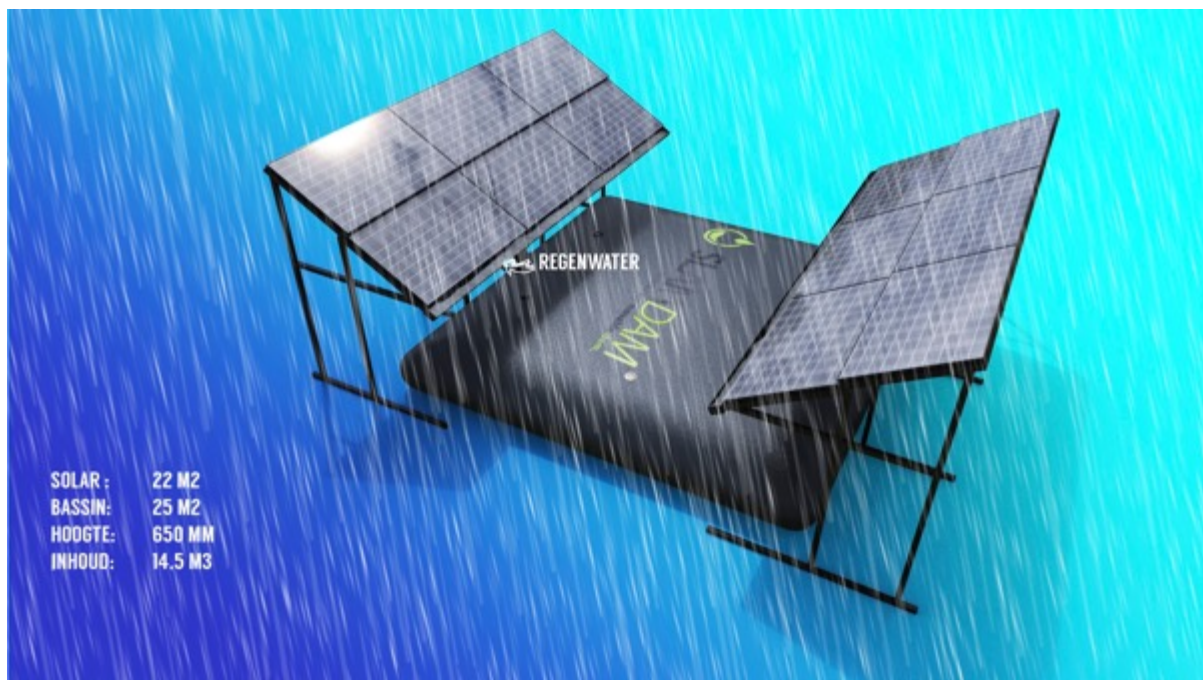
Water is typically used for crops, cleaning or drinking water for livestock.

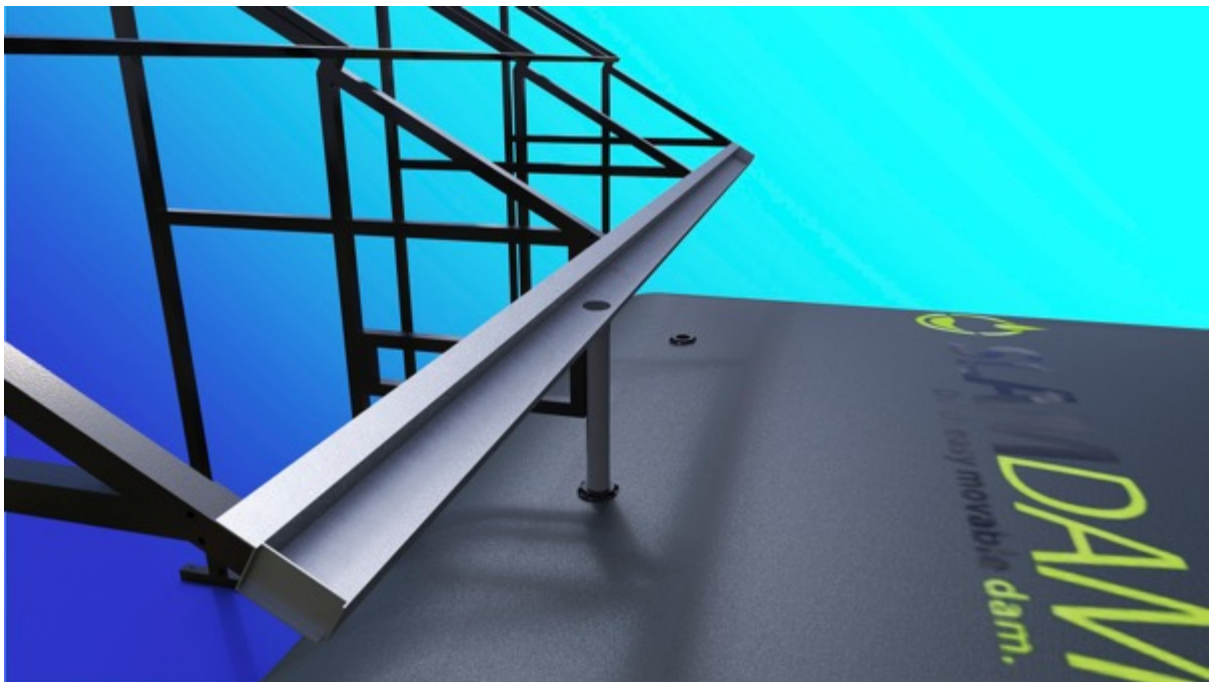
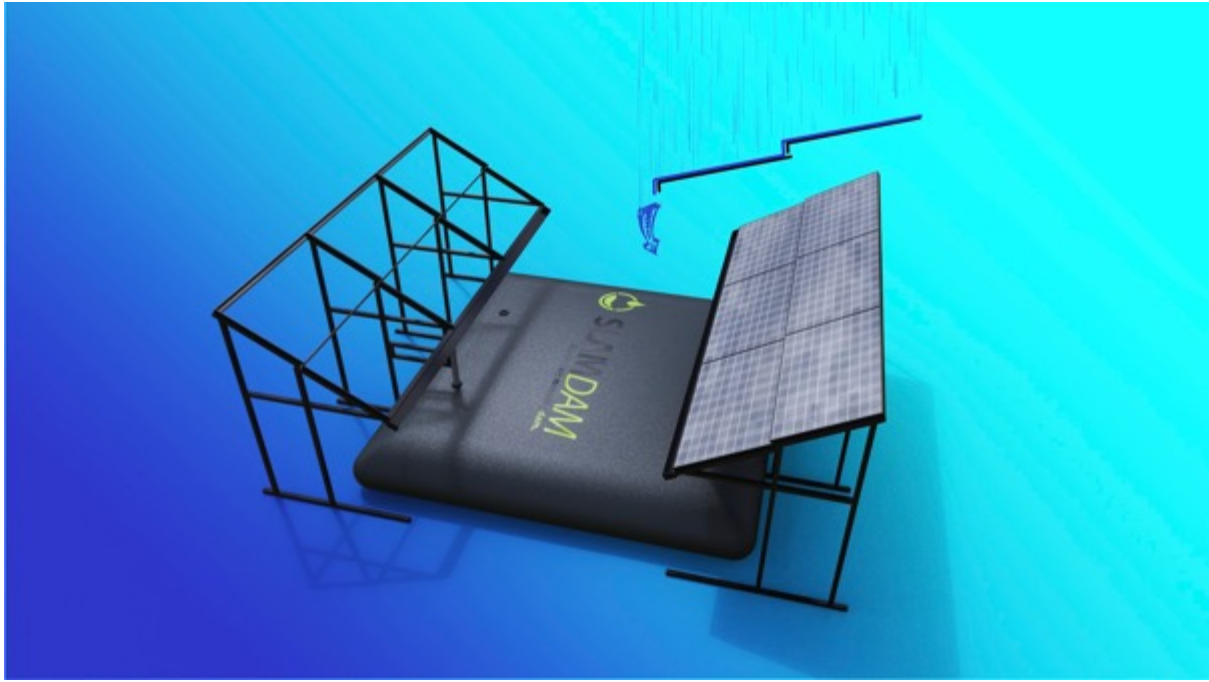
The 5X5 dam has a height of 65cm and can be filled with over 14,000 litres of water.

Filling the dam is done with rainwater. That rainwater is collected with solar panels. These form a roof as they are arranged in a tile-like fashion close to the dam.

The dam is 5x5 and the dam including panels is roughly 5x7 metres. A set is modular and can be extended.









3. Check Dams and Contour Bunds

3.1 Check Dams

Check dams are small, temporary or permanent structures constructed across a watercourse or drainage ditch to control water flow. They are designed to reduce the velocity of water, promote sedimentation, and enhance groundwater recharge. Check dams are typically made from locally available materials such as stones, concrete, or gabion baskets. They are used in areas with sloping terrain and seasonal streams to manage surface runoff and prevent soil erosion.

Key Features:

- **Water Storage:** Check dams create small reservoirs behind them, storing rainwater for various uses such as irrigation, livestock, and domestic purposes.
- **Groundwater Recharge:** The stored water gradually percolates into the ground, replenishing groundwater levels.
- **Soil Conservation:** By slowing down water flow, check dams reduce soil erosion and improve soil fertility.
- **Flood Control:** Check dams regulate water flow during heavy rains, reducing the risk of flash floods downstream.

3.2 Contour Bunds

Contour bunds are embankments constructed along the contour lines of a sloping field. They help in capturing and storing rainwater, reducing soil erosion, and promoting water infiltration. Contour bunds are commonly used in agricultural fields to improve water retention and soil moisture, thereby enhancing crop productivity.

Key Features:

- **Water Conservation:** Contour bunds trap and store rainwater, which can be used for irrigation and other purposes.
- **Soil Moisture:** They improve soil moisture levels, benefiting crop growth and reducing the need for supplemental irrigation.
- **Erosion Control:** By breaking the slope of the land, contour bunds minimize soil erosion and loss of fertile topsoil.
- **Groundwater Recharge:** The stored water infiltrates into the soil, replenishing groundwater resources.

4. Cisterns and Ferro-Cement Tanks

4.1 Cisterns

Cisterns are storage tanks designed to collect and store rainwater for various uses, including drinking, irrigation, and household purposes. They can be above ground or underground and vary in size depending on the water storage needs.

Key Features:

- **Water Collection:** Cisterns collect rainwater from roofs, courtyards, or other catchment areas through gutters and downspouts.
- **Storage Capacity:** They come in various sizes, from small household tanks to large community reservoirs, allowing for significant water storage capacity.
- **Material:** Cisterns can be made from different materials such as plastic, concrete, fiberglass, or metal, depending on the intended use and location.
- **Use:** The stored water can be used for drinking (after proper treatment), irrigation, and other domestic purposes, especially during dry periods when regular water sources are limited.

4.2 Ferro-Cement Tanks

Ferro-cement tanks are a type of cistern constructed using ferro-cement, a composite material made of cement mortar reinforced with layers of wire mesh and/or steel. This construction technique is known for its strength, durability, and cost-effectiveness.

Key Features:

- **Construction:** Ferro-cement tanks are constructed by applying a thin layer of cement mortar over a wire mesh framework, creating a robust and durable structure.
- **Durability:** The combination of cement and wire mesh makes these tanks highly durable and resistant to cracking, ensuring a long lifespan.
- **Cost-Effectiveness:** Ferro-cement is relatively inexpensive compared to other materials, making these tanks an affordable option for water storage.
- **Versatility:** They can be constructed in various shapes and sizes to meet specific water storage needs and space constraints.
- **Maintenance:** Ferro-cement tanks require minimal maintenance, making them suitable for use in rural and urban settings alike.

Applications and Benefits

Applications:

- **Domestic Use:** Storing rainwater for drinking, cooking, bathing, and other household needs.
- **Agricultural Use:** Providing a reliable water source for irrigation, livestock, and other farming activities.
- **Disaster Preparedness:** Serving as emergency water reservoirs in areas prone to natural disasters such as droughts or floods.

Benefits:

- **Water Conservation:** By capturing and storing rainwater, cisterns and ferro-cement tanks help conserve water and reduce reliance on traditional water sources.
- **Sustainability:** These systems promote sustainable water management practices, especially in regions with irregular rainfall or water scarcity.

- **Community Involvement:** Construction and maintenance of these tanks often involve local communities, fostering a sense of ownership and responsibility.
- **Cost Savings:** Reducing dependence on external water supplies can lead to significant cost savings for households and communities.