THE POTENTIAL FOR DOMESTIC RAINWATER HARVESTING IN LEBANON

ACTED

MARCH 2021

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The following report has been developed by ACTED Lebanon in the framework of the project WAAD "Providing Lebanese and Jordanian communities hosting Syrian refugees with improved WASH infrastructure and facilities at community, institution, and household level", funded by the EU MADAD Trust Fund and Region Sud in France. The publication serves to capitalize on the experiences gathered throughout the project implementation and to share best practices with actors implementing similar projects.

This publication was produced with the financial support of the European Union. Its contents are the sole responsibility of ACTED and do not necessarily reflect the views of the European Union.

ACTED would like to thank colleagues Antoine Hreiche, Hussam Hawa (Difaf Consultancies), Jawad Taher (WW-GVC) and Yann Pastel (Solidarites International)

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Executive Summary

Lebanon suffers from water mismanagement leading to public water supply shortages1, and households in Lebanon are accustomed to relying on a number of other sources to ensure they meet their demand: private boreholes, water trucking and purchasing bottled water for drinking. Domestic rainwater harvesting provides an alternative water source for non-potable household use, that has the potential to decrease household water costs and increase water supply, leading to increased water security, better hygiene outcomes and decreased pressure on surface and aquifer resources in Lebanon. Domestic Rainwater Harvesting (RWH) is defined as the capture, storage and management of rainwater flowing from roofs of buildings for domestic use. Rainwater harvesting is a complementary non-potable domestic water source to the Water Establishment public water services, and with legislation is Lebanon moving towards volumetric tariffing, has the potential to allow households to decrease the cost of water from the Water Establishment. Furthermore, climate change will greatly reduce natural water resources in the region by affecting precipitation, temperature, evaporation, relative humidity and solar radiation[2] and scaling up rainwater harvesting is in line with the mitigation measures proposed by the Ministry of Environment.

With funding from the EU MADAD Trust Fund, since 2019 ACTED has installed 43 RWH systems in residential and institutional buildings. The following report is an assessment of the impact of 33 residential systems installed in Berqayel, Akkar. The purpose of the 2018-2020 pilot was **to replace the costly reliance of residents on the water trucking service over the winter season, and reintroduce the idea of rainwater harvesting to the village**. Findings from the Berqayel pilot are described in the present report and meant to inform future programming. The results of this pilot were assessed using a mixed methodology: 1) focus group discussions, 2) quantitative data collection, 3) **Field visit (observation)** and **qualitative assessment and 4) household level data collection.** ACTED's team recorded the weekly results of the water meter readings at 10 of the RWH systems over a twelve-week period. The **weekly water demand of the household met** by the rainwater harvesting systems was tested across five water demand scenarios, from 50L to 150L per person. **100% of beneficiaries stated that the rainwater harvesting system was their primary source of domestic water** (above government supply, groundwater, and water trucking). When asked if the project had had any impact on their life beyond water supply, **81% of beneficiaries stated that this project had reduced their expenses**, with one beneficiary noting that in the past they often did not have sufficient money for water. The installation of rainwater harvesting systems are beneficial for households relying predominantly on water trucking. **This is evident in the fact that an additional 15 households in Berqayel self-**

[1] National Water Sector Strategy, Ministry of Energy and Water (2020)

[2] Traboulsi, Traboulsi (2017), *Rooftop level rainwater harvesting system*, Appl Water Sci (2017) 7:769–775

installed rainwater harvesting systems after the success of ACTED's pilot[3].

The installation of RWH systems uneconomical for households in view of its low return; however, **the cost of the system installed by ACTED (1,621 USD) is almost half (65%) the average cost of drilling a new borehole (2,467.5 USD) in Akkar, North Lebanon. ACTED has reviewed the design to install systems in line with National Guidelines for 900USD.** Furthermore**, the cost of systems self-installed by households (up to 500USD) is a fifth of the average cost of drilling a new borehole**. The benefits of rainwater harvesting systems can be enhanced when installed with water efficient fixtures (dual flush toilets, showerheads and low flow taps) to reduce the household domestic water demand by up to 48%[4].

In the past, rainwater harvesting and domestic utilization have been very frequent practices in different parts of the world. Since climate change, together with the rapid development of urban areas and population growth, is affecting the availability of water resources in many regions, the importance of collecting rainwater to partially meet the household water demand is now widely recognized. This pilot has demonstrated that rainwater harvesting has the potential to meet part of, or all, household demand in the winter months.

Figure 1. Rainwater harvesting system installed by ACTED on a residential building in Berqayel, Akkar.

[3] Reported during the focus ground discussion in June 2019
[4] Results of modelling of Al Ostuan Basin watershed, which found this mix of measures could reduce 48% of domestic demand. Modelling conducted by LDK Consultants on behalf of ACTED in December 2020 as part of an Integrated Water Management Plan for the watershed, funded by the EU MADAD Trust Fund and Provence-Alpes-Côte d'Azur

The Potential for Domestic Rainwater Harvesting in Lebanon

The Syrian crisis is one of the worst humanitarian crises of our time, displacing 4 million people from their home country. UNHCR has estimated that over 1 million refugees have fled to Lebanon since 2012, while the Lebanese government estimations approximate 1.5 million Syrian refugees present in the country. The influx has exacerbated pre-existing constraints in the country, and among the most pressing issues are polluted and limited water resources. Although Lebanon is in a fortunate hydrological position as compared to the rest of the Arab region[5], due to poor water governance and limited capacity to mobilize public financing in the sector, many residents are excluded from reliable and affordable services to meet their basic needs. With the current average coverage of the water network at around 79%[6], the majority of the water users are experiencing interruptions in supply – 20% of users receive water daily, averaging at 6 and 13 hours per day from public and non-public sources respectively[7]. Concerning the Syrian population, nationally there is a notable decrease in the reliance of public tap water - according to

Vulnerability Assessment of Syrian Refugees in Lebanon, 2019 (VASyR) - over the last five years (34% in 2015 to 21% in 2019). Only 21% of Syrian households (HH) rely on the tap water/water network to meet their basic needs due to the poor water quality, and rely mainly on bottled (42%) and trucked water (14%) as main sources of drinking water[8]. With the majority of water being secured through groundwater resources[9], the country's aquifers[10] cannot meet the growing demands and over-exploitation has decreased water availability and led to increased salinity of aquifers, especially on the coast. These issues are further exacerbated by lack of demand management policies: it was estimated in 2010 that Lebanon consumes what is equivalent to one and half times the annual ground and surface water replenishment[11]. Recent studies project that demand for water will jump from 1.5 billion cubic meters in 2015 to 1.8 billion cubic meters in 2035, pushing up the water deficit from 291 to 610 million cubic meters[12]. At the same time, use of non-conventional water sources, such as recycled wastewater, is limited due to lack of capacity and investment in wastewater management: as an estimated 8% of raw sewage is treated in Lebanon. Nationwide, 60% of the population is served by a sewer system[13], however, the capacity of the infrastructure (e.g. treatment plants, sewers) has already been exceeded in many areas, resulting in overflows and blockages requiring major repair and maintenance work, especially within high-risk coastal flood zones where informal urban settlements host a high proportion of Syrian refugees in Lebanon. In this context, ACTED is promoting the installation of rainwater harvesting systems (RWH) in line with the Ministry of Energy

[5] 789 m3 of water per capita per year as of according to the estimates of Food and Agriculture Organization of the United Nations (2017).
[6] 79% calculated as water users connected as compared to relative total HHs; regionally varying from 96% in Beirut to 55% in the North (Oxfam and Triangle, 2017, Feasibility Assessment for Water Service Provision to Informal Tented Settlements (ITS) in Lebanon: A case Study of North Beqaa).
[7] Le Borgne, Eric, and Thomas J. Jacobs. 2016. "Lebanon: Promoting Poverty Reduction and Shared Prosperity." World Bank, Washington, DC.
[8] Vulnerability Assessment of Syrian Refugees in Lebanon (Vasyr 2019); UNHCR, UNICEF, WFP, IAC Lebanon.
[9] Estimated at 0.5 BCM by MOEW.
[10] Keserwan Limestone Formation and the Sannine – Maameltein Limestone Formation.
[11] *Wastewater management and reuse in Lebanon,* Journal of Applied Sciences Research, Karam, Fadi, et. Al, 9(4): 2868-2879, 2013
[12] *The Policies and Actions Needed to Face the Growing Water Security Challenges in Lebanon*, Fransabank Center for Economic Studies 2018.
[13] Karam, Fadi, et. Al, Wastewater management and reuse in Lebanon….

and Water Guidelines as a complementary non-potable water supply to increase water availability and decrease pressure on water groundwater and networked water supplies. With funding from the EU MADAD Trust Fund, since 2019 ACTED has installed 43 RWH systems in residential and institutional buildings (Figure 2). The Installation of 8 rainwater harvesting systems at schools, one social development centre and one municipal building has increased water availability for 4451 students and 497 teachers. Additionally, the installation of 33 residential RWH systems on buildings has benefited a total 707 individuals in Berqayel Akkar. The following report is an assessment of the impact of these 33 residential systems.

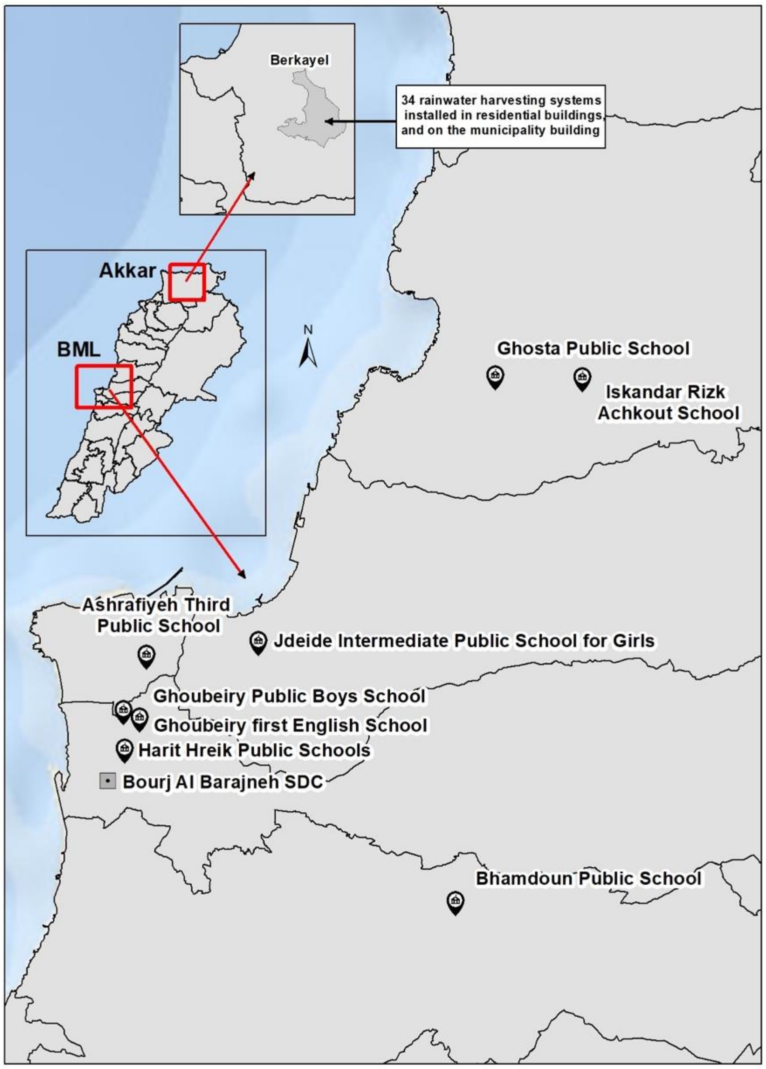

Figure 2. With funding from the EU MADAD Trust Fund, ACTED has installed a total of 43 rainwater harvesting systems in schools (8), one social development center, and one municipal building and 33 residential buildings in Berqayel Akkar.

ACTED in Lebanon

ACTED has been operational in Lebanon since 2006, working closely with local authorities and civil society stakeholders implementing priority humanitarian interventions as well as long term development programming notably on strengthening multi-stakeholder governance and accountability, public service upgrades, citizen participation and increasing economic opportunities. To address the impact of the Syrian crisis across society, ACTED's holistic approach comprises three specific levels of assistance provision, which are complementary and concurrent: a) targeted household level assistance ensures that vulnerable household's basic needs are met; b) community-level support increases the capacity and willingness of host communities and civil society actors to collaborate to overcome the challenges emerging from the crisis; c) local authority level support enables municipalities and local governments to maintain or improve basic service provision despite the instability and the demographic burden resulting from the influx and minimizes pressure placed on local resources and capacities. With regards to the water and sanitation programming, ACTED has been promoting multi-stakeholder water resource management since 2015, in particular those that reinforce the coordination between Water Establishments and local communities. This allowed for a nuanced understanding of water supply and demand gaps, in a context of rapid population growth and economic constraints. Since 2013 ACTED has been supporting the coordination between EBML and local authorities in Southern Beirut to rehabilitate and separate combined sewers, mitigating the local flooding and reducing sources of groundwater fecal contamination. Additionally, in partnership with the Ministry of Energy and Water (MoEW) and local communities, ACTED is implementing a River Basin Management (RBM) plan in the North which aims to highlight the communities across the basin that are most at risk of deficit in water supply and pollution, and support stakeholders to develop a joint vision and action plan for future integrated water management. In partnership with EU and local/international partners ACTED is currently implementing a nationwide water and sanitation program which aims at strengthening the capacity of water governance actors - public institutions and civil society to deliver sustainable services to local host and refugee communities in Lebanon. This action targets both duty bearers and rights holders with the holistic program, namely via: a) enabling Water Establishments to provide water and wastewater services efficiently and equitably in targeted localities; b) supporting civil society and local authorities to increasingly participate in sector governance and hold mandated institutions accountable; c) provision of the support to Lebanese water services related to Refugee crisis response via inter alia wastewater services and the technical capacity building in the selected Informal Tented Settlements.

Results of a pilot study in Berqayel, Akkar

February 2021

Lebanon suffers from water mismanagement leading to public water supply shortages[14], and households in Lebanon are accustomed to relying on a number of other sources to ensure they meet their demand: private boreholes, water trucking and purchasing bottled water for drinking. The estimated number of unlicensed private wells is almost three times higher than the number of licensed private wells (about 55,000 to 60,000 wells)[15], making it challenging for authorities to regulate groundwater abstraction. Furthermore, aquifers[16] in Lebanon do not always yield clean water. Due to excessive pumping of aquifers in coastal regions in Lebanon, seawater intrusion has led to high salinity of groundwater[17]. Studies show that lack of wastewater treatment has also compromised groundwater quality in urban areas[18] and rural areas[19], and an ACTED assessment of water quality in 127 boreholes in rural Akkar found that 27% of the samples were contaminated with e.coli and 6% with nitrate[20].

The practice of relying on numerous water sources is costly for households. Drilling a new borehole in Lebanon depends on the depth and characteristics of the aquifer, and in Akkar households reported[21] that it costs on average 70,500 LBP (47 USD[22]) per meter to drill a new borehole, and the depth of boreholes is on average 52.5m ranging from 11m to 147m, resulting in an average cost of 2,467.5 USD[23]. As a result of the high capital cost and the ongoing operation costs of the pump, neighbors share boreholes which can lead to disputes over water access.[24] In areas where public water supplies are not available and groundwater abstraction is not feasible, households are obliged to buy water from private water trucking companies. Water trucking companies are not regulated in Lebanon, and as a result the source, quality and volume of water extraction are not monitored, and the price of one m^3 varies per region.

Domestic rainwater harvesting provides an alternative water source for non-potable household use, that has the potential to decrease household water costs and increase water supply,

[14] National Water Sector Strategy, Ministry of Energy and Water (2020)

[15] Assessment of Groundwater Resources of Lebanon (2014), MoEW, UNDP

[16] An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials.

[17] Saadeh, M., & Wakim, E. (2017). Deterioration of Groundwater in Beirut Due to Seawater Intrusion.

[18] Koussa, H., & Nawas, T. (2017). Bacterial Contamination of Urban Water Wells in the Nuwayri Region of Beirut – Lebanon.

[19] Water supply network in Lebanon: The example of Borj El Arab. (2018, March 27). Retrieved from https://www.premiere-urgence.org/en/14107/

[20] 127 water samples tested by ACTED in 2017 from private boreholes used for domestic water in Akkar, North Lebanon

[21] Reported during a household assessment conducted by ACTED of 333 households in nine villages in Akkar in 2016

[22] This cost was collected in 2016 when the exchange rate was 1USD = 1,500 LBP. An updated cost assessment is required to determine the cost in LBP due to currency fluctuations since July 2019.

23 These costs were reported to ACTED in 2016, and have not been adjusted for inflation; however the average cost of the boreholes drilled in the ten years prior to the assessment only were calculated

[24] In Berqayel, Akkar, a beneficiary reported to ACTED a dispute with neighbors over the use of a shared borehole in June 2019 during a focus group discussion with 25 community members

leading to increased water security, better hygiene outcomes and decreased pressure on surface and aquifer resources in Lebanon. Domestic Rainwater Harvesting (RWH) is defined as the capture, storage and management of rainwater flowing from roofs of buildings for domestic use. Typical RWH systems consist of three basic elements: the collection system (area which produces runoff because the surface is impermeable or infiltration is low), the conveyance system (through which the runoff is directed, e.g. by pipes) and the storage system (where water is accumulated or held for use). The storage system consists of above or underground tanks. The **quantity of water harvested** depends on the precipitation, the roof catchment area, the diameter of the guttering and the volume of storage.

Rainwater harvesting systems are an effective measure to minimize the use of treated water for non-potable use, and supply drinking water in areas where the existing sources cannot meet the water needs. In addition, storing rainwater at building level reduces the flow of stormwater drains, and the cost of managing runoff. [25] In the context of urban water cycle, RWH aims to minimize the effects of seasonal variations in water availability due to droughts and dry periods, and to enhance the reliability of domestic water supply and reduce the dependence on the mains water supply. Additional benefits include effective management of surface runoff, mitigation of flooding and soil erosion, reduction of water bills, etc. Nevertheless, there are limitations in implementing RWH techniques or relying on RWH as a source of supply, the main disadvantage being the unpredictable and often irregular supply which results in large storage space requirements. Larger storage volumes are difficult to implement as they are more costly. Finally, as rainwater usually carries small pollutant loads (depended on the location, roof building materials and collection system construction), treatment and disinfection is generally needed for rainwater treatment to non-potable standards.

Lebanon receives between 400 and 1800mm of water per year, 750 to 1000mm on the coast and rising to 1800mm in higher altitudes, while Beqaa is drier and receives 400 to 800mm. The concept of the rainwater harvesting is not new: this low-cost technology has been practiced in Lebanon for hundreds of years, but in modern days its adoption has been static. In the present scenario, due to the inability of water infrastructure to meet the growing demand, one study concluded that if widely adopted in Lebanon, domestic rainwater harvesting could collect around 23 MCM (70 % of the current deficit in the domestic water supply)[26] thus increasing the available water per m^2 of building by 0.4 m^3 per year[27], and considerably reducing the rate of surface runoff of rainwater at the coastal zones where rainwater is not captured at all and goes directly to the sea.[28]

Rainwater harvesting is a complementary non-potable domestic water source to the Water Establishment public water services, and with legislation is Lebanon moving towards volumetric

[25] Freni, Liuzzo (2019), *Effectiveness of Rainwater Harvesting Systems for Flood Reduction in Residential Urban Areas Water* 2019, 11, 1389; doi:10.3390/w11071389

[26] Traboulsi, Traboulsi (2017), *Rooftop level rainwater harvesting system*, Appl Water Sci (2017) 7:769–775

[27] Estimating an average roof catchment size of 150m²

[28] Appl Water Sci (2017) 7:769–775, DOI 10.1007/s13201-015-0289-8

tariffing, has the potential to allow households to decrease the cost of water from the Water Establishment. Furthermore, climate change will greatly reduce natural water resources in the region by affecting precipitation, temperature, evaporation, relative humidity and solar radiation[29] and scaling up rainwater harvesting is in line with the mitigation measures proposed by the Ministry of Environment, including 1) the protection of groundwater from salinization in coastal areas; 2) the implementation of water demand side management strategies to reduce water consumption in the domestic, industrial and agriculture sectors to reduce pumping from groundwater[30].

With funding from the EU MADAD Trust Fund, and under the WAAD Consortium, ACTED implemented a Rainwater Harvesting pilot in Berqyael, Akkar where **RWH systems were installed in 33 residential buildings** (Figure 3 and 4) and one municipal building. The purpose of the 2018-2020 pilot was **to replace the costly reliance of residents on the water trucking service over the winter season, and reintroduce the idea of rainwater harvesting to the village**. Findings from the Berqayel pilot are described in the present report and meant to inform future programming.

Figure 3. ACTED installation of rainwater harvesting system in Berqayel, Akkar

[29] Traboulsi, Traboulsi (2017), *Rooftop level rainwater harvesting system*, Appl Water Sci (2017) 7:769–775

[30] Ministry of Environment, available online: http://climatechange.moe.gov.lb/water

Selection of Berqayel, Akkar for a pilot

Berqayel municipality was selected for a **domestic rainwater harvesting pilot** after community consultations in 25 villages in Akkar as part of the EU funded 'Ta-cir'. During the stakeholder meetings, access to water was identified as a key need in five of the municipalities (Ayyat, Kherbet Daoud, Tel Maayan, Berqayel and Qalamoun). ACTED conducted an initial assessment in each of these municipalities, and Berqayel was prioritised for the pilot given areas suffering from water shortage, had the largest local population (26,500 inhabitants) hosting a large number of refugees (2,500 individuals) and the municipality demonstrated strong commitment to the project.

In the absence of public water supply from the North Lebanon Water Establishment (NLWE), households relied on trucked water, private boreholes and springs. In fact, households in Households in Berqayel were in debt due to the high cost of water trucking.

Figure 4: Rainwater harvesting systems installed in the municipality of Berqayel, Akkar.

There were between 180-200 private boreholes in Berqayel[31], and residents with private boreholes supplied water to their neighbors for a monthly subscription fee of approximately 25,000LBP[32].

Many households relying on neighbors' boreholes had to supplement this source with water trucking during the summer months when there was a lower yield of groundwater. Some households in the village relied on springs; however, the capacity of these springs was reported at low in the few years preceding 2019, due to a period of low precipitation[33].

The yearly average precipitation in Berqayel is 745mm per year[34], with the majority of rainfall between October and March (Figure 5).

[31] Reported to ACTED during a focus group discussion in Berqayel in July 2019
[32] As above
[33] As above
[34] Source: National Guideline for Rainwater Harvesting Guidelines (2016), Ministry of Energy and Water and UNDP

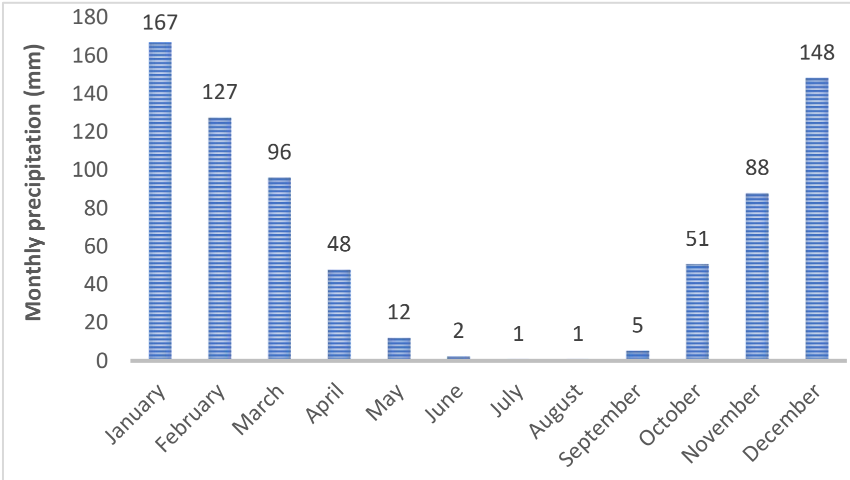

Figure 5. Average monthly precipitation, Berqayel Akkar (mm) *(Source: RWH Guidelines, MoEW)*

After informing the municipality of Berqayel that they were selected for the pilot, posters were placed throughout the village announcing a public meeting to launch the rainwater harvesting pilot (Figure 6). Northlife[35], a social media group in North Lebanon, shared the announcement of the pilot and photographs of the event on their page. During the public meeting in November 2018, ACTED's technical team provided an overview of the systems and registered interest of the community members. ACTED's technical team then conducted site visits to each household who registered interest in the pilot to assess the technical feasibility, household size and current household water source to select a total of **33 buildings to install the pilot systems**. Berqayel municipality building was additionally selected to provide a showcase system for the wider community.

[35] *Northlife* is a social media page in North Lebanon with 113,744 followers

Figure 6. Posters announcing community meeting to launch of rainwater harvesting pilot in Berqayel, Akkar

Design of the rainwater harvesting systems for non-potable water uses

The rainwater harvesting system comprised of a guttering collection, downpipes with a connection to a groundwater tanks, micro and media water treatment and a pump reconnecting the water to storage on the roof (Figure 7). A strainer was installed on the inlet of the stormwater downpipes to collect any debris from the roof; however, a first flush system (separate downpipe to be emptied after events) was not installed, which would provide additional water quality benefits. ACTED installed an additional 4 m³ polyethylene aboveground storage tanks for each building, which along with existing tanks in place, contributed overall to a storage of between 8 to 12 m³ per building.

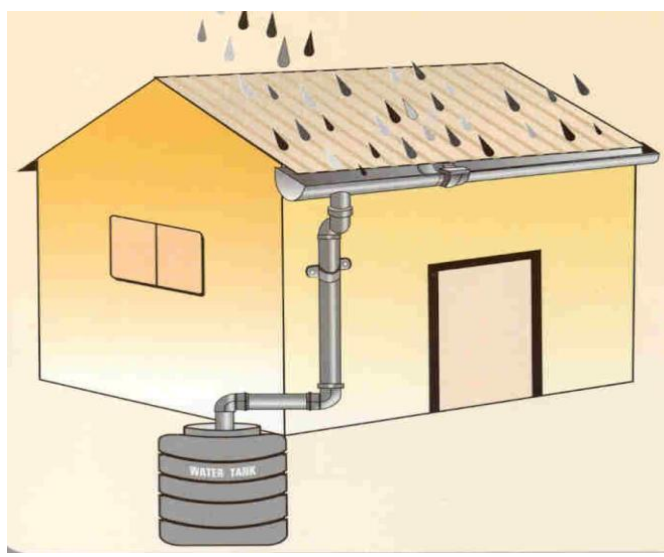

Figure 7. Simple schematic of a RWH system with guttering, downpipes and above ground water tank

During rain events, the entire tank storage system was utilized for the rainwater harvesting system. The overflow from the tanks was allowed to flowed from the lid of the rooftop tank. The design of the systems were based on the the *National Guideline for Rainwater Harvesting in Lebanon*.

The **costs of the RWH systems** ranged from 1,050$ to 1,950$ (including installation costs). All RWH systems included two double layer PVC water tanks of 2m3 capacity each (unit cost of each tank = 212$), a small electrical water pump (Italian made) of 0.5 HP, high pressure up to 12m, and flow rate 35 L/min (unit cost of the pump = 96$), rain water filters (media and micro filter with all needed accessories, supply and installation) (cost = 152$), and 2 valves (5'' two way valves) at the connection between the collection tank and the 5'' PVC pipe from the roof (unit cost = 202$). The total costs ranged depending on the length/number of PVC and HDPE pipes and related accessories (fittings, elbows, connections, etc.) needed to be installed on the external walls of the buildings (cost = 3.5-7 $/m)

Assessment methodology

The results of this pilot were assessed using a mixed methodology:

1) a **focus group discussion** with 25 community members in June 2019, to gather qualitative information regarding community acceptance, water access before and after the pilot, impact of the project on household expenditure and relations with neighbours, satisfaction with the project implementation and communication from ACTED, operation and maintenance of the systems and potential for project scale up.

2) **Quantitative data collection** through installation of water meters on a sample of ten systems for a twelve-week period between January 8 2020 and March 25 2020 (based on their willingness to participate) to record the volume of water harvested per system. During the monitoring period, a total of 22 rainy days were registered. The total (cumulative) volumes of rainwater recovered by the installed RWH systems ranged from 20m3 to 67m3 of rainwater collected (per system), which represents an average of 0.9-2.9 m3 per rainy day per system/household.

3) **Field visit (observation)** and **qualitative assessment** of 11 households where systems were installed in June 2019 (different households to those having undertaken the metric assessment) to monitor the post implementation of works, the household acceptance and use of the new technology, and impact of the systems on household expenditure and access to water.

4) A **household assessment** in March 2020 (21 beneficiaries) which was conducted remotely due to the Covid-19 pandemic to determine the impact of the system after two winter periods on HH finances and water access, the household satisfaction with the installed systems. In January 2021, the local focal point was interviewed for information on household-level cost of self-installation, and 7 beneficiaries were contacted to triangulate this information, as well as update water meter reading.

Results of rainwater harvesting pilot

Volume of water captured

"The community is extremely happy and positively surprised. The installations targeted one of their most urgent needs, and households who received installations felt immediate and palpable benefits. It is the first time that an NGO proposes a plan for water management and actually implements it. The results are outstanding and should be duplicated so that even more households benefit"

MAYOR OF BERQAYEL

ACTED's team recorded the weekly results of the water meter readings at 10 of the RWH systems over a twelve-week period; however results were not captured during week 9 and week 11. Figure 5 below illustrates the positioning of the water meter to capture the volume of water pumped from the groundwater tank to the roof water tank. The water pump is manually controlled and must be turned on during rainfall events to pump water from the groundwater tank to the roof tank. Beneficiaries were asked that during the period of the data collection, if an alternative water sources of water were used to fill the rooftop tank directly as to not contribute to the quantity of water being calculated by the water meter.

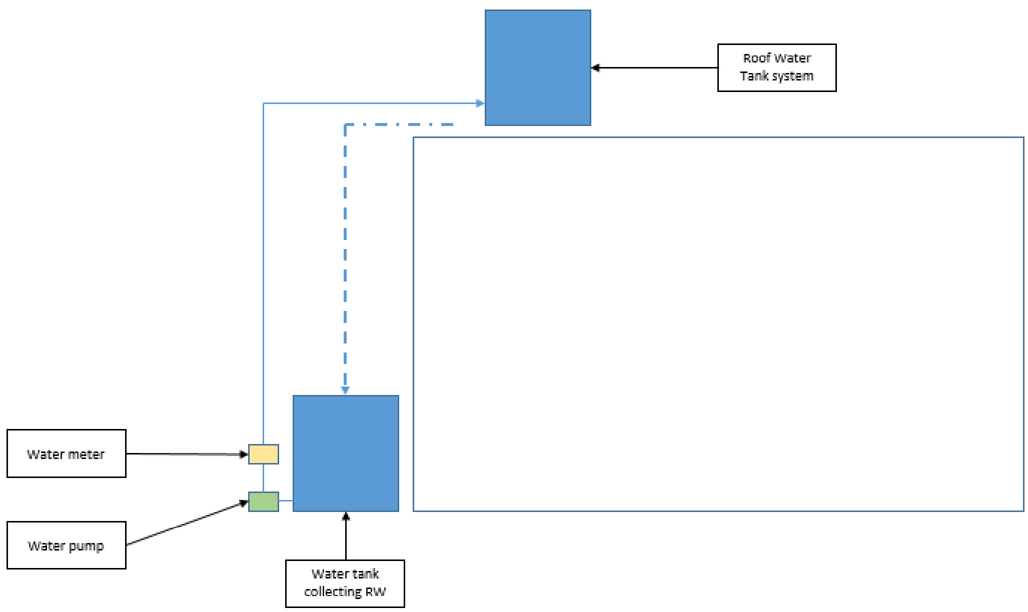

Figure 8. Positioning of water meter in RWH system during ACTED data collection

The water meter readings were recorded by ACTED's staff weekly between January 2 2020 and March 25 2020 (weeks 1 to 12), and additionally in January 2021 (Week 56), and the roof catchment size of each location is recorded in the table below.

Additionally, the number of days of rain were recorded per week; however, for future case studies, it is recommended to use a rain gauge to record the actual daily mm of rain and to accurately record the rainfall days.

Site	Roof size (m^2)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9 and 10	Week 11 and 12	Week 56
1	N/A	1.06	N/A	2.8	3.9	6.7	6.7	7.6	7.6	10.6	N/A	N/A
2	200	0.6	2.0	6.9	8.5	14.6	15.0	15.4	16.7	19.2	20.0	N/A
3	N/A	19.2	30.9	36.8	47.8	52.9	60.4	69.2	74.3	92.4	N/A	N/A
4	400	1.7	3.2	5.3	9.2	15.2	27.7	40.6	40.6	46.7	51.7	97.9
5	240	12.1	13.2	18.5	20.7	22.4	28.1	30.1	32.8	39.2	45.7	70
6	150	12.8	13.8	16.6	19.4	21.5	25.7	26.0	26.3	28.4	30.5	40.3
7	240	7.6	12.0	17.2	20.8	23.2	28.0	32.5	36.4	44.4	55.8	N/A
8	N/A	17.6	21.0	26.5	32.4	34.8	41.3	44.5	45.3	52.4	60.9	N/A
9	N/A	12.2	14.8	20.2	24.0	27.8	33.1	37.0	37.3	45.0	54.4	N/A
10	180	12.6	15.5	26.5	32.1	34.6	43.8	46.4	49.1	60.3	67.3	89.3

Table 1. Water meter readings at 10 RWH system locations (m^3 per week)

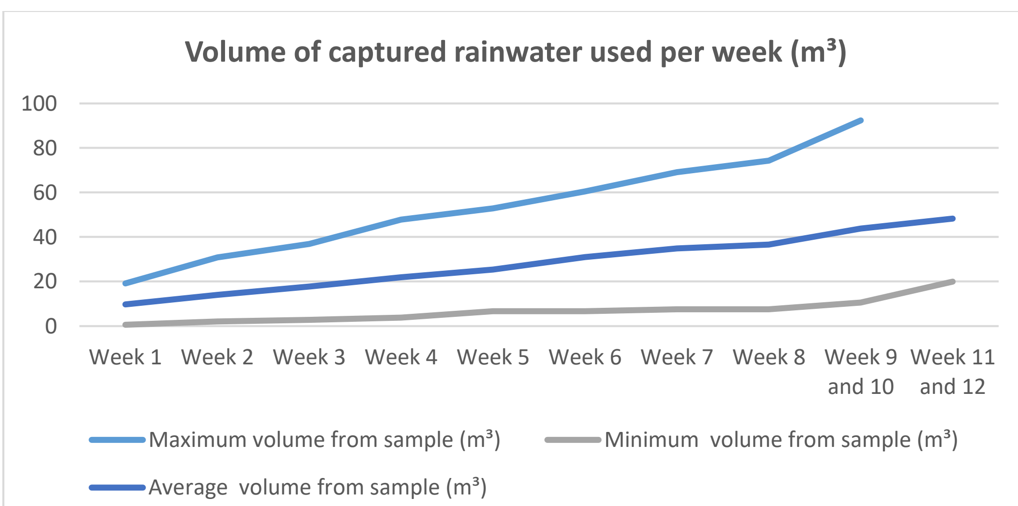

Figure 9. Minimum, maximum and average volume of captured rainwater used per week (m^3) for the sample of 10 locations

Table 2 below indicates the weekly volume of water captured at each rainwater harvesting location that was pumped to the roof water tank. ***Site 1*** is the municipality of Berqayel building, and the low volume of captured water weekly indicates that the water pump was not turned-on during rainfall events. As such, this location has not been included in the analysis. Finally, provided there are no data records for week 9 or week 11, the volume of water recorded in both week 10 and week 12 was averaged across both weeks.

There is a risk that beneficiaries pumped another source of water from the groundwater tank to the roof tank that was recorded by the water meter. This could have been avoided if the water meter was installed on the inflow pipe (the pipe connecting the roof level tank to the ground level tank), and this will be considered for future installations. As a result, it was decided to omit the higher volumes (highlighted in grey) in the analysis of the average, as given the variance from the mean weekly value there is a likelihood a second source of water was utilized by the households in this week. The residential building RWH systems (***Site 2 to 12***) collected on **average 4.1 m³ of water weekly** between January 8 2020 and March 25 2020.

Site	Roof size (m²)	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
1	N/A	1.1	0.9	0.9	1.1	2.8	0.0	0.9	0.0	1.5	1.5	N/A	N/A
2	200	0.6	1.4	4.9	1.5	6.2	0.4	0.3	1.3	1.2	1.2	0.4	0.4
3	N/A	19.2	*11.7*	5.9	*11.0*	5.0	7.5	8.7	5.1	*9.1*	*9.1*	N/A	N/A
4	400	1.7	1.5	2.1	3.9	6.0	*12.6*	*12.9*	0.0	3.1	3.1	2.5	2.5
5	240	12.1	1.1	5.3	2.2	1.7	5.7	2.0	2.7	3.2	3.2	3.2	3.2
6	150	12.8	1.0	2.8	2.8	2.1	4.2	0.3	0.3	1.1	1.1	1.0	1.0
7	240	7.6	4.4	5.2	3.7	2.4	4.8	4.5	3.9	4.0	4.0	5.7	5.7
8	N/A	17.6	3.4	5.5	6.0	2.4	6.5	3.2	0.8	3.6	3.6	4.2	4.2
9	N/A	12.2	2.6	5.4	3.9	3.7	5.3	3.9	0.4	3.8	3.8	4.7	4.7
10	180	12.6	2.9	*11.0*	5.6	2.4	*9.2*	2.6	2.7	5.6	5.6	3.5	3.5
Average		**10.7**	**2.3**	**4.6**	**3.7**	**3.6**	**5.5**	**3.2**	**1.9**	**3.8**	**3.8**	**3.2**	**3.2**

Table 2. Weekly volume of water pumped from the groundwater tank to roof tank (m³ per week)

The **weekly water demand of the household met** by the rainwater harvesting systems was tested across five water demand scenarios. The values of 50L and 100L per person were selected as according to the **World Health Organization (WHO), between 50 and 100 liters of water per person per day** are needed to ensure that most basic needs are met and few health concerns arise. In Scenario 6, a daily demand of 150L per person was modeled in line with the daily per capita water consumption in the Ministry of Energy and Water's National Water and Wastewater Strategy (2020). The values in grey in Table 2 were replaced with the weekly average for the water demand analysis.

- **Scenario 1:** 1m³ per building per day, the volume of water provided by the NLWE to a residential building
- **Scenario 2:** 100L provided per person for the household size at each location *(Table 2. Locations 2 to 10)*
- **Scenario 3:** 50L provided per person for the household size at each location *(Table 2. Locations 2 to 10)*
- **Scenario 4:** 100L per person provided for an average household in Lebanon (5 people)
- **Scenario 5:** 50L per person provided for an average household in Lebanon (5 people)
- **Scenario 6:** 150L per person provided for an average household in Lebanon (5 people)

A basic water balance model was built using excel to determine the weekly demand that was met at each RWH system. For each scenario, the daily demand was multiplied to determine the weekly demand. For the first water balance assessment of each scenario ("***water balance assessment 1***"), it was assessed if the weekly demand was met by the weekly water captured. As such the results of this water balance assessment are higher than 100% in some cases when the water harvested exceeded the demand for that week. This assessment would indeed be further strengthened by a daily water balance model; however data was collected on a weekly basis[36]. For the second water balance assessment of each scenario ("***water balance assessment 2***"), any remaining water at the end of the week (ie. Weekly volume harvested – weekly demand = remaining water), was carried on to the water balance of the following week. As such, for ***water balance assessment 2***, the maximum demand that can be met is 100%. For each scenario, a color coding has been provided to allow the reader to easily assess if the water demand has been exceeded for the week (green), if more than ten percent of the water demand has been met (orange), or less than ten percent of the water demand was met (red).

[36] For future studies, data should be collected at a daily timescale in order to accurately compute the deficit (runoff – water pumped to the upper tank – water discharged through the overflow) $V=\int(I - O1 - O2).dt$

Results of Scenario 1

This scenario assumed a daily water demand of 1 m^3 per building per day, the volume of water provided by the NLWE to a residential building.

Across the sample of 9 residential sites, 27% to 153%[37] per cent of this weekly demand was met (Table 3). Table 4 demonstrates that six of the sites (66%) in the sample could meet more than 10% of this demand weekly when the excess rainwater captured was carried over to the following week

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	9%	20%	70%	22%	88%	6%	5%	19%	18%	6%
3	274%	33%	85%	53%	72%	108%	125%	73%	129%	N/A
4	25%	21%	30%	55%	86%	79%	46%	N/A	44%	35%
5	172%	16%	75%	32%	25%	81%	29%	39%	46%	46%
6	183%	14%	40%	40%	30%	60%	4%	4%	15%	15%
7	109%	62%	74%	52%	34%	69%	64%	56%	57%	82%
8	251%	49%	78%	85%	34%	93%	46%	11%	51%	60%
9	175%	37%	76%	55%	53%	76%	55%	6%	55%	67%
10	180%	41%	66%	80%	35%	132%	37%	38%	80%	50%
Average	**153%**	**33%**	**66%**	**53%**	**51%**	**78%**	**46%**	**27%**	**55%**	**40%**

Table 3. Scenario 1, ***Water balance assessment 1***: Percentage of weekly demand met by water harvested each week

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	9%	20%	70%	22%	88%	6%	5%	19%	18%	11%
3	100%	100%	100%	100%	100%	100%	100%	100%	100%	N/A
4	25%	21%	30%	55%	86%	79%	46%	N/A	44%	71%
5	100%	89%	75%	32%	25%	81%	29%	39%	46%	92%
6	100%	97%	40%	40%	30%	60%	4%	4%	15%	30%
7	100%	71%	74%	52%	34%	69%	64%	56%	57%	100%
8	100%	100%	100%	100%	100%	98%	46%	11%	51%	100%

[37] When the value is higher than 100% it demonstrates that for this particular week, the water harvested exceeded the water demand for the same week.

9	100%	100%	88%	55%	53%	76%	55%	6%	55%	100%
10	100%	100%	88%	100%	100%	100%	75%	38%	86%	99%
Full Demand met (%)	**78%**	**44%**	**22%**	**33%**	**22%**	**22%**	**11%**	**13%**	**11%**	**38%**

Table 4. Scenario 1, ***Water balance assessment 2***: Water demand met by the system, with excess water harvested carried into the following week

Results of Scenario 2

This scenario assumed a daily water demand of 100L provided per person for the number of users at each site (column 2). The figures for the total number of individuals at sites was not accurate, and as such the average across the whole sample of residential buildings was used for each site (20 individuals). Across the sample of 9 residential sites, 24% to 108% per cent of this weekly demand was met (Table 5). Table 6 demonstrates that five of the locations in the sample could meet more than 10% of this demand weekly when the excess rainwater captured was carried over to the following week.

Site	**Number of users**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9/10**	**Week 11/12**
2	35	2%	6%	20%	6%	25%	2%	1%	5%	5%	2%
3	***20****	137%	16%	42%	26%	36%	54%	62%	37%	65%	N/A
4	15	16%	14%	20%	37%	57%	52%	30%	N/A	29%	24%
5	17	101%	10%	44%	19%	15%	47%	17%	23%	27%	27%
6	15	122%	9%	27%	27%	20%	40%	3%	3%	10%	10%
7	5	218%	124%	148%	105%	67%	138%	129%	112%	113%	297%
8	***20****	126%	24%	39%	43%	17%	46%	23%	6%	25%	30%
9	***20****	87%	18%	38%	28%	27%	38%	28%	3%	27%	34%
10	13	139%	32%	51%	61%	27%	102%	29%	29%	62%	38%
Av.		**105%**	**28%**	**48%**	**39%**	**32%**	**58%**	**36%**	**24%**	**40%**	**51%**

Table 5. Scenario 2, ***Water balance assessment 1***: Percentage of weekly demand met by water harvested each week

Site	Number of users	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	35	2%	6%	20%	6%	25%	2%	1%	5%	5%	3%
3	***20****	100%	53%	42%	86%	86%	54%	62%	37%	65%	N/A
4	15	16%	14%	20%	37%	57%	52%	30%	N/A	29%	47%
5	17	100%	11%	44%	19%	15%	47%	17%	23%	27%	54%
6	15	100%	31%	27%	27%	20%	40%	3%	3%	10%	20%
7	5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
8	***20****	100%	50%	39%	86%	17%	46%	23%	6%	25%	60%
9	***20****	87%	18%	38%	28%	27%	38%	28%	3%	27%	67%
10	13	100%	71%	51%	100%	59%	100%	30%	29%	66%	77%
Full Demand met (%)		**67%**	**11%**	**11%**	**22%**	**11%**	**22%**	**11%**	**13%**	**11%**	**13%**

Table 6. Scenario 2, ***Water balance assessment 2***: Water demand met by the system, with excess water harvested carried into the following week

Results of Scenario 3

This scenario assumed a daily water demand of 50L provided per person for the number of users at each site (column 2). Across the sample of 9 residential sites, 48% to 211% per cent of this weekly demand was met (Table 7). Table 8 demonstrates that six of the locations in the sample could meet more than 10% of this demand weekly when the excess rainwater captured was carried over to the following week.

Site	Number of users	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	35	5%	12%	40%	13%	50%	3%	3%	11%	10%	3%
3	***20****	274%	33%	85%	53%	72%	108%	125%	73%	129%	N/A
4	15	33%	28%	40%	74%	115%	105%	61%	N/A	58%	47%
5	17	203%	19%	89%	37%	29%	95%	34%	46%	54%	54%

6	15	244%	18%	54%	53%	40%	80%	6%	6%	20%	20%
7	5	437%	249%	296%	209%	135%	276%	258%	223%	227%	1094%
8	***20****	251%	49%	78%	85%	34%	93%	46%	11%	51%	60%
9	***20****	175%	37%	76%	55%	53%	76%	55%	6%	55%	67%
10	13	278%	64%	101%	123%	54%	203%	57%	59%	123%	108%
Av.		211%	57%	95%	78%	65%	115%	72%	48%	81%	162%

Table 7. Scenario 3, ***Water balance assessment 1***: Percentage of weekly demand met by water harvested each week

Site	**Number of users**	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9/10**	**Week 11/12**
2	35	5%	12%	40%	13%	50%	3%	3%	11%	10%	6%
3	***20****	100%	100%	100%	100%	100%	100%	100%	100%	100%	N/A
4	15	33%	28%	40%	74%	100%	100%	80%	N/A	58%	94%
5	17	100%	100%	100%	48%	29%	95%	34%	46%	54%	108%
6	15	100%	100%	100%	70%	40%	80%	6%	6%	20%	40%
7	5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
8	***20****	100%	100%	100%	100%	100%	98%	46%	11%	51%	100%
9	***20****	100%	100%	88%	55%	53%	76%	55%	6%	55%	100%
10	13	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Full demand met (%)		78%	78%	67%	44%	56%	44%	33%	38%	33%	63%

Table 8. Scenario 3, ***Water balance assessment 2***: Water demand met by the system, with excess water harvested carried into the following week

Results of Scenario 4

This scenario assumed a daily water demand of 100L provided per person for average household size in Lebanon (5 individuals). Across the sample of 9 residential sites, 91% to 306% per cent of this weekly demand was met (Table 9).

Table 10 demonstrates that when excess rainwater captured was carried over to the following week, the weekly demand was met every week at five of the sites, one site met the demand for most weeks and in only two sites there was one week each where less than 10% of the demand was met.

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	17%	41%	140%	44%	176%	12%	9%	38%	35%	11%
3	548%	66%	170%	106%	144%	215%	250%	146%	259%	N/A
4	49%	42%	60%	110%	172%	157%	91%	N/A	88%	74%
5	345%	33%	151%	63%	50%	161%	58%	79%	91%	153%
6	366%	28%	81%	80%	61%	119%	9%	8%	30%	30%
7	218%	124%	148%	105%	67%	138%	129%	112%	113%	297%
8	502%	98%	156%	171%	68%	185%	91%	23%	101%	228%
9	350%	74%	153%	110%	107%	152%	111%	11%	109%	277%
10	361%	83%	131%	160%	70%	264%	74%	76%	160%	171%
Average	**306%**	**65%**	**132%**	**105%**	**102%**	**156%**	**91%**	**55%**	**110%**	**135%**

Table 9. Scenario 4, ***Water balance assessment 1***: Percentage of weekly demand met by water harvested each week

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	17%	41%	100%	84%	100%	87%	9%	38%	35%	23%
3	100%	100%	100%	100%	100%	100%	100%	100%	100%	N/A
4	49%	42%	60%	100%	100%	100%	100%	N/A	100%	100%
5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
6	100%	100%	100%	100%	100%	100%	100%	52%	6%	59%
7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
8	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Full Demand met (%)	78%	78%	89%	89%	100%	89%	89%	75%	78%	75%

Table 10. Scenario 4, ***Water balance assessment 2***: Water demand met by the system, with excess water harvested carried into the following week

Results of Scenario 5

This scenario assumed a daily water demand of 50L provided per person for average household size in Lebanon (5 individuals). Across the sample of 9 residential sites, 110% to 613% per cent of this weekly demand was met (Table 11). Table 12 demonstrates that when excess rainwater captured was carried over to the following week, the weekly demand was met every week at seven of the sites and at the remaining two sites demand was met for most weeks.

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	35%	82%	281%	88%	351%	23%	19%	77%	70%	113%
3	1096%	131%	340%	211%	288%	430%	499%	292%	517%	N/A
4	99%	84%	119%	221%	344%	314%	183%	N/A	175%	508%
5	689%	65%	302%	127%	99%	323%	115%	157%	183%	805%
6	732%	55%	161%	160%	121%	239%	17%	17%	61%	372%
7	437%	249%	296%	209%	135%	276%	258%	223%	227%	1094%
8	1005%	195%	313%	341%	137%	370%	183%	46%	203%	805%
9	699%	148%	306%	221%	214%	303%	221%	23%	218%	1054%
10	722%	166%	263%	319%	140%	528%	149%	153%	320%	442%
Average	613%	131%	264%	211%	203%	312%	183%	110%	219%	577%

Table 11. Scenario 5, ***Water balance assessment 1***: Percentage of weekly demand met by water harvested each week

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	35%	82%	100%	100%	100%	100%	100%	100%	100%	100%
3	100%	100%	100%	100%	100%	100%	100%	100%	100%	N/A
4	99%	84%	100%	100%	100%	100%	100%	N/A	100%	100%
5	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

7	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
8	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
9	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Full Demand met (%)	**78%**	**78%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Table 12. Scenario 5, ***Water balance assessment 2***: Water demand met by the system, with excess water harvested carried into the following week

Results of Scenario 6

This scenario assumed a daily water demand of 150L provided per person for average household size in Lebanon (5 individuals), in line with the daily per person consumption recommended by the Ministry of Energy and Water. Across the sample of 9 residential sites, 37% to 204% per cent of this weekly demand was met (Table 13). Table 14 demonstrates that when excess rainwater captured was carried over to the following week, the weekly demand was met every week at two of the sites, partially to fully meet weekly at five of the sites and at the remaining two sites demand was met for most weeks and only once or twice was less than 10%.

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	12%	27%	94%	29%	117%	8%	6%	26%	23%	8%
3	365%	44%	113%	70%	96%	143%	166%	97%	172%	N/A
4	33%	28%	40%	74%	115%	105%	61%	N/A	58%	47%
5	230%	22%	101%	42%	33%	108%	38%	52%	61%	61%
6	244%	18%	54%	53%	40%	80%	6%	6%	20%	20%
7	146%	83%	99%	70%	45%	92%	86%	74%	76%	109%
8	335%	65%	104%	114%	46%	123%	61%	15%	68%	81%
9	233%	49%	102%	74%	71%	101%	74%	8%	73%	90%
10	241%	55%	88%	106%	47%	176%	50%	51%	107%	99%
Average	**204%**	**44%**	**88%**	**70%**	**68%**	**104%**	**61%**	**37%**	**73%**	**57%**

Table 13. Scenario 6, ***Water balance assessment 1***: Percentage of weekly demand met by water harvested each week

Site	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9/10	Week 11/12
2	12%	27%	94%	29%	100%	25%	6%	26%	23%	15%
3	100%	100%	100%	100%	100%	100%	100%	100%	100%	N/A
4	33%	28%	40%	74%	100%	100%	80%	N/A	58%	94%
5	100%	100%	100%	94%	33%	100%	46%	52%	61%	100%
6	100%	100%	100%	70%	40%	80%	6%	6%	20%	40%
7	100%	100%	100%	97%	45%	92%	86%	74%	76%	100%
8	100%	100%	100%	100%	100%	100%	100%	74%	68%	100%
9	100%	100%	100%	100%	100%	100%	100%	11%	73%	100%
10	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Full Demand met (%)	**78%**	**78%**	**78%**	**44%**	**67%**	**67%**	**44%**	**25%**	**22%**	**63%**

Table 14. Scenario 6, ***Water balance assessment 2***: Water demand met by the system, with excess water harvested carried into the following week

"I used to be burdened with debt because of my water needs, having to pay over $133 every month in order to purchase water. This project truly changed my life"

BERQAYEL RESIDENT #1

"A lot of things changed. First of all, we no longer have to pay for water during winter, second we now have an abundance of water (during winter), so we don't worry - we do not need water tanks nor wells nor anything else"

BERQAYEL RESIDENT #2

In March 2020, over a year after the installation of the rainwater harvesting systems, 21 of the 34 beneficiaries of the harvesting systems partook in the post assessment (on a voluntary basis). All of the beneficiaries stated they were 'very satisfied' with the project and consistent with the demand modelling results in the section above, **100% stated that the rainwater harvesting system was their primary source of domestic water** (above government supply, groundwater, and water trucking). When asked if the project had had any impact on their life beyond water supply, **81% of beneficiaries stated that this project had reduced their expenses**, with one beneficiary noting that in the past they often did not have sufficient money for water. When asked for additional feedback, 29% of the sample reported that since the installation they were only purchasing water from water trucks during the summer at a cost of 15,000LBP per trip. it is likely the currency fluctuation has led some of the prices to increase

Cost of the rainwater captured

The rainwater harvesting systems installed by **ACTED cost on average 1,620 USD**, including all the items listed in Table 15 below.

It should be cautioned that these prices were collected in 2019 prior to the economic crisis and an updated market review of the materials is required.

Material	Unit	ACTED system			Households self-installed (15)	
		Unit cost	Average units	Cost (USD)	Item included?[38]	Cost (USD)
Provide and fix 75mm(3")/ 100mm (4")/ 110mm (5") diameter PVC pipes with all needed accessories (fittings, elbows, connection etc…) supply and installation mainly on the external walls	m	7.1	30	218	Reduced quality	30
Provide and fix 5" two-way valve at the connection between the collection tank and the 5" PVC pipe from the roof. Supply and installation	Item	202.2	2	404	Yes	Unknown
Provide and Fix 1" HDPE pipe with all needed accessories (Fitting, Elbows, connection, Etc.…) supply and installation mainly on the external walls)	m	3.49	50	175	Reduced quality	Unknown
Provide and install rain water filters (Media and Micro filter with all	Item	2	151.65	303	Not included	

[38] Data collected during KI interview with municipality focal point in January 2021

needed accessories) supply and installation						
Provide and install small electrical water pump (Italy Made), 0.5 HP, high pressure up to 12m, with flow rate 35L/min	Item	1	96.05	96.05	Reduced quality	Exact price unknown
Provide and install double layer PVC water tank 2m3 with all accessories (pipe, elbow….)	Item	2	212.30	424.62	100L – 2000L	50 – 200 USD
Total cost (USD)				**1620**		**200- 500**

Table 15. Materials and cost for installation of domestic rainwater harvesting systems

Based on the cost of alternative water supply (water trucking at 5000 LBP per m³) an assessment of **the period of pay back** of such a system (i.e. When the cost of the system is recovered through savings on water trucking) was calculated (Table 16). A simple assessment of the yearly savings from rainwater harvesting was to the water balance of **Scenario 4** - 100L/p/day for a family of five was conducted. This Scenario was selected as it represented the mid-range of demand scenarios modelled (between 50L to 150L), and additionally represented a realistic weekly volume of water a family of five would purchase during the non-rainy months (2.5m³ weekly). It should be noted that this assumed water consumption is likely higher than the real consumption for the region of study, and that the water consumption could be halved. [39] The percentage of water demand met weekly for each of the scenarios was multiplied by the cost of water trucking for the same volume of water. The results of the savings per week are illustrated in Figure 7. Considering the current fluctuations in the USD- LBP exchange rates, the average capital cost of the system (1620 USD) was converted into LBP at two rates: 1) **Exchange rate 1:** the official rate of 1,500 (total cost 2,431,500 LBP) and 2) **Exchange rate 2:** the increased rate of 3,900 (total cost 6,321,900 LBP). It is assumed that the beneficiary is relying solely on water trucking.

[39] Households buying water in rural areas of Akkar do not have the luxury of toilet flushing and use small containers for water flushing and regulate water flow from water taps and showers, daily consumption of water per person could be halved. The estimation of 100L per person per day is reflective of areas not buying water due to water scarcity. *Feedback provided by Difaf (Environmental Consultancy in Lebanon).*

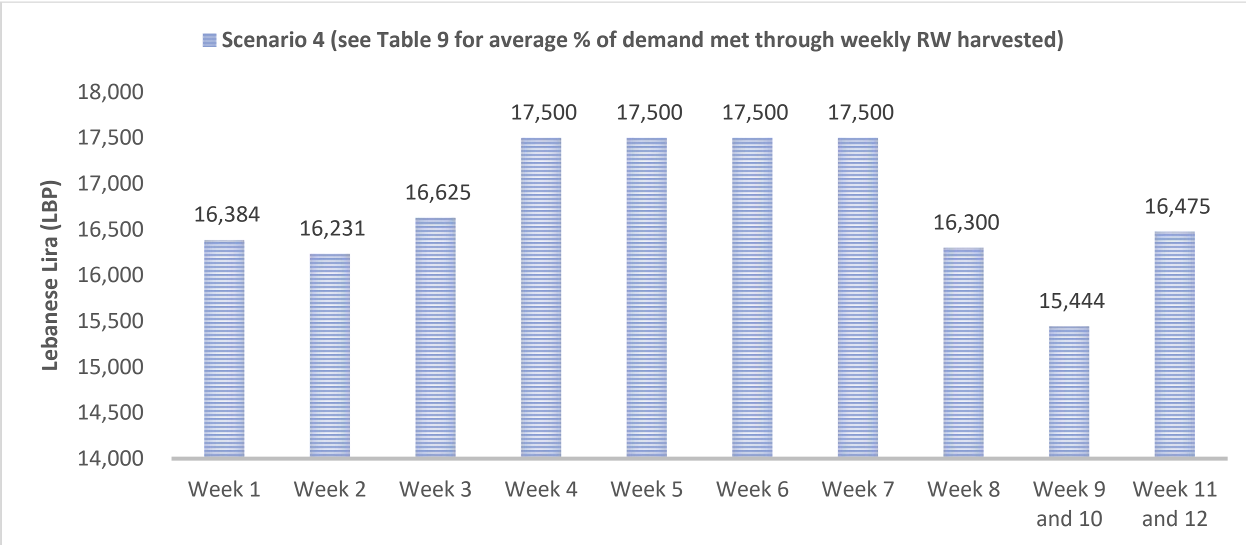

Figure 8. Average weekly cost savings substituting 2.5m³ of water trucking with RWH harvested for a family of 5 (Lebanese Lira)

	Scenario 4 (Demand 100L/p/day, 5 individuals)
Savings over 12 weeks (LBP)	167,459
Savings over yearly winter season (24 weeks) (LBP)	334,919
Cost of water trucking to meet yearly demand (LBP)	912,500
% of year costs of yearly demand saved	37%
Cost savings as a percentage of total cost of system (at 1,500 LBP to 1 USD)	14%
Years to pay back system (at 1,500 LBP)	7.3
Cost savings as a percentage of total cost of system (at 3,900 LBP to 1 USD)	5%
Years to pay back system (at 3,900 LBP)	18.9

Table 16. Assessment of cost recovery period of the rainwater harvesting system

The capital cost is a barrier for many families in Lebanon, and the payback period (when compared to the cost of water trucking) is between 7 to 19 years across the two scenarios listed in Table 16. The installation of RWH systems uneconomical for households in view of its low return; however, **the cost of the system installed by ACTED (1,621 USD) is almost half (65%) the average cost of drilling a new borehole (2,467.5 USD) in Akkar, North Lebanon.** Furthermore**, the cost of systems self-installed by households (up to 500USD) is a fifth of the average cost of drilling a new borehole**. The investment of grant funding, in particular in low-income areas relying on water trucking and/or with a high capital or ongoing cost of private boreholes, is indeed beneficial, and will serve as a complementary water source once public water services are available in these areas.

The installation of rainwater harvesting systems are beneficial for households relying predominantly on water trucking. **This is evident in the fact that an additional 15 households in Berqayel self-installed rainwater harvesting systems after the success of ACTED's pilot**[40]. These households installed one tank of 100L to 2m³, and did not install water filters, a proper guttering system or a high-end pump and the total cost of the system was between 200 USD (100L tank) to 500 USD (2000L tank). A comparison of the system to the ones installed by ACTED is available in Table 15. This option would provide a supplementary source of water on rainy days; however, as the water is not treated and could only be used for very limited domestic purposes. To identify areas where households would most benefit from rainwater harvesting, an assessment of the locations relying on water trucking in Lebanon is required.

To encourage further scale up, an investigation is required to determine a more cost-effective design for households. One researcher[41] proposed rainwater harvestings systems that collected water directly from the roof into the roof-level water storage tank, without conveying the water through gutters and to a groundwater tank to be repumped to the roof. This option requires a less powerful pump, and no gutters or ground water storage tanks and the author estimated this system would cost approximate 234 EUR[42]. The author also estimates savings of around 7 % of the amount of electric energy usually needed to pump water from an aquifer well and ground or underground tank. However, this option is limited by the existing storage volume of the household (as it does not include additional storage in the cost) and has less overall storage than the systems installed by ACTED.

The benefits of rainwater harvesting systems can be enhanced when installed with water efficient fixtures (dual flush toilets, showerheads and low flow taps) to reduce the household domestic water demand by up to 48%[43], providing households the

[40] Reported during the focus ground discussion in June 2019
[41] Traboulsi, Traboulsi (2017), *Rooftop level rainwater harvesting system*, Appl Water Sci (2017) 7:769–775
[42] Source: As above. Note, the cost was estimated by author in 2014, and an updated assessment of the costs is required to accurately compare the systems
[43] Results of modelling of Al Ostuan Basin watershed, which found this mix of measures could reduce 48% of domestic demand. Modelling conducted by LDK Consultants on behalf of ACTED in December 2020 as part of an Integrated Water Management Plan for the watershed, funded by the EU MADAD Trust Fund and Provence-Alpes-Côte d'Azur

equivalent of approximately 100L of domestic water uses for a real demand of 50L. The installation of solar pumps also feasible to install systems with a solar pump to reduce the cost of fuel for households; however, entail a high capital cost.

Conclusions and recommendations

The cost of the system is likely still a barrier for households in Lebanon, who should be likely offered an incentive to install rainwater harvesting systems. Globally there are examples of schemes to encourage the uptake of rainwater harvesting in urban areas (to reduce stormwater runoff, improve green building performance, decrease surface/groundwater reliance), and a global policy review is required and an assessment of the feasibility of such schemes in Lebanon. In considering avenues for scaling up in Lebanon, the following points should be considered:

- The **pricing of the volumetric tariffing** could be designed in a way to encourage households to install rainwater harvesting systems. For example, the pricing could be designed to change the price during the winter season to increase the cost of water, and reduced prices for water in the summer season.
- It is also recommended that rainwater harvesting is considered as part of **municipal urban storm water planning** and ACTED is piloting this in Beirut as part of an EU funded project. Domestic rainwater harvesting can also reduce the frequency of urban flooding, and the resulting cost of damages. In Sicily, Italy, a study found that **the installation of building level domestic rainwater harvesting systems reduced the flooding events by half**[44]**.** A comparable study should be implemented in Lebanon. A flood risk assessment[45] by the Centre for National Scientific Research (CNRS) in Lebanon found that the flood damage equivalence to constructions summed cultivation up to reach 32 M$ for residential structures, 29 M$ for non-residential structures, and 0.3 M$ for refugees' tents at a 10 year flooding frequency (i.e. A stormwater event that occurs in every ten

[44] The study measured the effectiveness of domestic rainwater harvesting to reduce urban flooding and increase domestic supply in the residential area is located in the city of Palermo, Sicily (Southern Italy) and includes 408 single-family houses. In this area, sewage and rainwater are collected and conveyed by the urban drainage system. The catchment area is approximately 1.6 km². Source: Freni, Liuzzo (2019), *Effectiveness of Rainwater Harvesting Systems for Flood Reduction in Residential Urban Areas Water* 2019, 11, 1389; doi:10.3390/w11071389

45 ABDALLAH, C., HDEIB, R., 2015. FLOOD RISK ASSESSMENT AND MAPPING FOR LEBANON- UNDP/CNRS, LEBANON, 93 P. + ANNEX

years), while structures' content losses were estimated at 27M$, 54M$, 0.5 M$ respectively for the same flood frequency.

- In a country facing electricity shortages, and Water Establishments relying on generators and the cost of fuel to pump water when the public electricity supply is not available, supporting households to install rainwater harvesting and decentralize water services could be a viable option. An economic study comparing the cost of rebate programs to encourage household installation of rainwater harvesting systems with that of pumping centralized water should be conducted.
- There are no standards or regulations in Lebanon concerning rainwater harvesting and the use of rainwater. The Rainwater Harvesting Guidelines (produced in collaboration between UNDP and the MoEW) set clear requirements regarding the collection, storage, treatment and use of harvested rainwater and the Ministry of Energy. The National Water Sector Strategy (2020, Ministry of Energy and Water) proposes a Strategy for Rainwater Harvesting should be developed. The scaling up of domestic rainwater harvesting requires coordination of a number of stakeholders. The Ministry of Energy and Water have expressed the importance of working on **building codes and with urban planning authorities** to make rainwater harvesting a must in the design of all new buildings.
- Collecting rainfall for reuse is particularly valuable in the dry summer months, when there are shortages of other water sources. In order of this to be profitable, a larger storage and more costly storage is required to collect and store water for the dry summer months.
- ACTED is currently revising the design of the systems to further reduce costs, and has redesigned the system to 800-900USD. Additionally, for future interventions, the design of the rainwater harvesting systems from concrete blocks and masonry blocks will be considered to improve the social impact in the area and create an opportunity for short term labour and employment instead of the use of PE tanks. A comparative cost analysis is required between both designs. Furthermore, the space occupied by two circular water tanks (2000L each) represents 75% of the equivalent volume for a rectangular volume of the same height. Therefore, the adoption of rectangular shape tanks would allow an increase of 33% of the water capacity and allow for a higher coverage of water needs for the same space allocation[46].
- ACTED planned to conduct water testing of the system with technical partner Notre Dame University; however, this was not feasible due to the restrictions on travel due to ongoing crises in Lebanon. A water testing campaign of the rainwater harvesting systems will be conducted once it is feasible, and the results shared.

In the past, rainwater harvesting and domestic utilization have been very frequent practices in different parts of the world. Since climate change, together with the rapid development of urban areas and population growth, is affecting the availability of water resources in many regions, the importance of collecting rainwater to partially meet the household water demand is now widely recognized. This pilot has demonstrated that rainwater harvesting has the potential to meet part of, or all, household demand in the winter months.

[46] Recommendation provided by Difaf Consultancy