Chapter 8

Solar-powered water systems for vulnerable rural communities: Alleviating water scarcity in Iraq

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ABSTRACT

Deteriorating water quality and decreasing water quantity are causing a water crisis in Iraq. The crisis is having a profoundly negative impact on people's livelihoods and on the economy. In the most water-stressed areas, vulnerable people have had to move from rural areas where water is scarce to urban areas, placing additional pressure on the water supply.

To mitigate the impact of water scarcity on the most vulnerable people in rural areas, the United Nations Children's Fund has worked in partnership with the Iraqi Water Authorities on a programme to increase access to more resilient water services in some highly vulnerable rural and conflict affected areas of Iraq where water services are unreliable. One major contributing factor to the problem of access to water was the unreliability of the electrical supply, particularly in the summer months. The programme identified that an alternative to grid electrical power was needed to achieve a more reliable source of energy for water provision.

The programme installed solar-powered water systems in two vulnerable districts in northern Iraq: Shekhan district, Ninewa, and Makhmur, Erbil. These systems are now providing sustainable, predictable and reliable water services to two vulnerable districts which had previously suffered extensively from power shortages and service interruptions. The water from the new solar-powered systems provides access to safe water for refugees and internally displaced people, as well as local communities. Importantly, the programme has increased water conservation and

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efficiency and helped to strengthen community resilience. It has also highlighted the need for adaptive and innovative technological solutions, which can support more effective disaster response and recovery.

Keywords: water scarcity, solar energy, rural water supply.

8.1 INTRODUCTION

The limited availability of water in sufficient quantity and quality is a daily challenge facing millions of people in Iraq, where water scarcity is both a physical and economic issue. Water is scarce due to an arid climate, but also because there is a lack of capacity and investment to improve water services and, as a result, water demand is not being met. Iraq has been identified as being under high water stress and is facing an acute water crisis (Maddocks & Luo, 2015). Water stress has manifested itself in a number of ways in the country, with water shortages and water pollution leading directly to violent protests, such as those experienced in Basra in 2018, and displacement of people as a direct result of water scarcity (UNICEF, 2019).

The water crisis in Iraq threatens its economic development and the achievement of its commitments to achieve the UN Sustainable Development Goals (SDGs). According to the last WHO-UNICEF Joint Monitoring Programme (JMP) report in 2019, while 91% of the rural population have access to at least a basic water service, only 46.5% have access to a safely managed service. It is a similar situation for sanitation access; the JMP shows that 88% of the population have access to at least a basic sanitation service, but only 45% have access to a safely managed sanitation service (WHO & UNICEF, 2019a, 2019b).

Poor access to safe water and sanitation services poses significant health risks and increases the risk of waterborne diseases, especially among vulnerable groups such as children and women (UNICEF in Iraq, 2019). Access to water and sanitation services varies significantly across different populations in the country, with some communities affected disproportionately by poorer access to services. According to the Government of Iraq, poverty is geographically concentrated in certain areas where it is deeply rooted and chronic and is associated with living in rural areas, amongst other factors (Ministry of Planning, 2010a, 2010b). According to the JMP data for safely managed water services, 64% of the urban population have access to a safely managed water service, compared to only 46.5% in rural areas (WHO & UNICEF, 2019a, 2019b).

Climate change and water scarcity pose a severe threat in Iraq, with large parts of the country facing potential desertification. As a direct result of water reduction into parts of Iraq, it has been estimated that 250 km^2 of Iraq's land is already becoming barren each year, causing a significant negative impact on livelihoods in rural areas (Ministry of Planning, 2010a, 2010b).

Water scarcity is already severely and directly affecting communities: in 2019, over 5000 families were displaced from the southern region of Iraq, particularly from Basra, Missan and Thi-Qar governorates, due to a lack of water (United Nations, 2018). The International Organization for Migration (IOM) has similarly reported that 11% of IDPs left their homes due to water scarcity – exceeding conflict, security and livelihoods as a reason for migration (IOM, 2018). Incidents of tension over water access are now common throughout the country, reported in 38 different locations in Baghdad (UN, 2013). Water-related conflicts have been reported in Kirkuk, with farmers in Karbala abandoning their farms and livelihoods due to water scarcity (*ibid.*). Such events clearly illustrate one of the many ways water crises can impact vulnerable populations.

The Government of Iraq's Ministry of Planning outlined the main reasons for the country's water crisis in a UN 2010 Environmental Survey, as follows:

- inadequate management of water resources at all levels;
- large volumes of water required by construction projects;
- lack of a long-term strategic water infrastructure project; and
- lack of long-term, comprehensive strategy to combat the impact of water scarcity.

It is against this backdrop that effective solutions must be found to overcome three specific and significant barriers to sustainable water services in Iraq: dwindling water resources; the deterioration of the water and sanitation infrastructure over recent decades and; unstable access to power to properly operate the requisite systems.

To improve access to sustainable, resilient, affordable, equitable and safe water services, the Government of Iraq and the United Nations Children's Fund (UNICEF) developed solar-powered water supply systems for two vulnerable areas in rural Iraq: Shekhan, Ninewa, and Makhmur, Erbil. The programme was implemented in cooperation with the local government water service provider in the northern governorates.

Initially, water scarcity interventions had focussed simply on rehabilitating basic water systems and services to enhance access to sustainable drinking water services. However, due to lack of fuel and financial resources, maintaining the restored water systems proved challenging. To overcome this barrier, UNICEF worked with the Iraqi water administration to explore the potential of solar power as an alternative source of energy for water systems in the most vulnerable areas. The initiative to transition to a more sustainable source of energy was augmented by a range of other interventions to enhance resilience to water scarcity, such as water conservation behaviours and water efficiency. The programme offers a cost-effective solution to the provision of a sustainable, safe, low-carbon water services to vulnerable and displaced people.

This chapter examines the context for water resources in Iraq, considers the problems faced by the water sector and assesses the role of water authorities and

institutions. It then describes the actions undertaken by UNICEF and the Iraqi water authorities in Shekhan and Makhmur, as well as the details of the solar-powered water system solution and goes on to analyse the overall impact of the programme.

8.2 CONTEXT

8.2.1 Water context in Iraq

The Tigris and Euphrates rivers are the main sources of water in Iraq, providing 93%–98% of Iraq's total water resources, while groundwater accounts for approximately 2%–7%. Other potential water resources such as desalinated water, treated wastewater and reused agriculture drainage water are still either underdeveloped or unused in Iraq (Abd-El-Mooty *et al.*, 2016).

Official figures from the Ministry of Water Resources (MoWR) indicate that the average annual flow of both the Tigris and Euphrates have decreased significantly over recent decades, with flows from the Tigris declining from 66 billion cubic metres (BCM) in the early 1970s to 28 BCM in 2015 and the Euphrates down from an average of 30 BCM in the 1970s to 8 BCM in 2015.

Figures from the Government's Water and Land Resources Strategy (MoWR, 2014) show that the agriculture sector requires over 40 BCM each year (see Figure 8.1), representing almost 60% of the entire national water requirement. Much of this consumption is wasted due to the inefficient methods used by farmers to irrigate their crops (Ministry of Water Resources, 2014).

If nothing is done to address the critical water situation and integrate resilience into water and sanitation services (UNDP, 2014), current projections indicate that the country's water deficit (the difference between the available water resources and the water needed) will increase from 11 BCM in 2015 to 29 BCM by 2035 – meaning an estimated 28% of the population will not have access to at least basic water and sanitation services (*ibid.*).

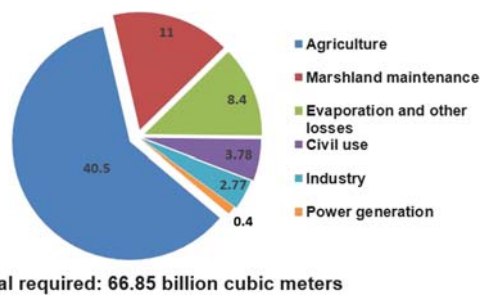

Figure 8.1 Iraq's annual water demand in BCM. (*Source*: Ministry of water resources, 2014).

8.2.2 The causes of increasing water scarcity in Iraq

There are a range of reasons for Iraq's water scarcity crisis, which affects the ability of providers to supply reliable water services. The elements described below are all factors causing or exacerbating the severity of the water crisis in Iraq.

8.2.2.1 Upstream riverine development

Iraq shares the water flow from the Tigris and Euphrates with Turkey, Syria and Iran, with only 8% of Iraq's total water supply coming from internal sources (Adamo *et al.*, 2018).

As a result of anticipated increased water demand in Turkey and Syria, it is likely that these countries will significantly increase their share of Tigris and Euphrates water resources in the coming years, drastically reducing river flows into Iraq (Lelieveld *et al.*, 2016; Tabari & Willems, 2018).

There has been significant upstream development on the Tigris and Euphrates in Turkey and Syria over the past 30 years, with construction of dozens of water-retention structures already completed and many others under construction, all having a direct impact upon water flows into Iraq (HRW, 2019a, 2019b, 2019c). Iran also has dam projects on the Tigris tributaries within its territory and there are dams in Syria on the Euphrates for hydroelectric power and irrigation (*ibid.*). A report by the International Association of Universities predicted a worst-case scenario of both the Tigris and Euphrates rivers being depleted by 2040, if no action is taken to secure a share of water for Iraq (IAU, 2011). In addition, precipitation in the region is expected to fall by up to 16% by the middle of this century (*ibid.*).

8.2.2.2 Climate change

In recent years, temperature increases and reduced rainfall have led to severe drought) in Iraq. Drought has affected both agriculture and water supply, as most Iraqi wheat production is rain-fed. The combination of reduced rainfall and extreme heat has led to an increase in evaporation and evapotranspiration rates, resulting in a large volume of water being lost every year, especially in southern Iraq (Frenken, 2009).

The extended drought conditions have had a detrimental impact on the lives of Iraqi citizens. The poor access to a reliable water service has led to a deterioration in livelihoods and crop production, an increase in unemployment and an increase in some diseases such as typhoid and diarrhoea (UNICEF, 2016).

8.2.2.3 Increased water consumption

The Iraqi population has grown from around 10 million in 1970 to almost 41 million in 2021 (worldometer, 2021). This population increase has been accompanied by a large number of refugees fleeing the conflict in Syria, as well as an increasing level

of internally displaced people (IDPs), leading to concentrations of people and placing additional stress on existing services (IAU, 2011). To mitigate the impact of the reduced volumes of available water and the increased water demands, the Iraqi government has attempted to respond to reduce water consumption from 350 to 200 litres per capita per day (l/c/d), through a number of programmes aimed at raise awareness of water conservation and reuse (Ministry of Municipalities & Public Work, 2011).

Another factor which has contributed to poor water service delivery, in addition to the reduced volumes and increased water demand, has been an increase in competition for electricity, with demand rising by 24% in 2017 alone (World Bank, 2018).

In Iraq, 98.9% of electricity used is generated from burning fossil fuels, with oil representing 66.7% (413 terawatt-hours (TWH)) and gas, 32.1% (199 TWH) (Oxford University, 2019). The remainder includes water-based hydroelectric generation, representing 1% (6 TWH) and a small amount of solar generation, 0.2% (1 TWH) (*ibid.*). Oil and gas supplies are subject to significant levels of interruption, resulting in an unstable energy supply across most of the country (*ibid.*). While the Ministry of Electricity has built more plants to boost power production, this has increased water consumption as oil and gas power stations use steam in the generation process.

The demand for electricity, with its associated increase in water demand, is only likely to increase in the near future. Large numbers of industrial facilities, which have been out of operation (or near peak capacity) since 2003 or earlier, are expected to resume operations in the next few years, placing even greater demands on energy generation and therefore the water supply sector (World Bank, 2018).

A further reason for increased water demand in the country is the restoration of the marshes of Iraq, which were purposefully and extensively dried out under the earlier regime. These marshlands have been partially revived since the fall of the regime in 2003 and were named as a UNESCO World Heritage site in 2016. Work to restore the marshes continues, and it is believed 70%–75% will be restored within the next few years. The marshes require 15 BCM of water for restoration without improving water quality and an extra 5 BCM to improve water quality (World Bank, 2006).

8.2.2.4 Deteriorating critical infrastructure

In 2019, the United Nations' Humanitarian Needs Assessment found that 2.2 million people do not have access to safe and appropriate water and sanitation services in Iraq, of which 47% are children (Iraq Multiple Indicator Cluster Survey, 2018). However, even for those systems which are operational, most of the country's water facilities are working below the minimum operating standards of the World Health Organization (WHO) (*ibid.*).

The protracted conflict in Iraq has resulted in the destruction and extensive damage to water infrastructure, with decades of sanctions further compounding the situation. Cumulatively, these have severely impacted the expansion or rehabilitation/updating of water systems, as well as impeding the maintenance of the operational systems. The estimated damage to the Water, Sanitation and Health (WASH) sector in Iraq pre-2014 is US$1.4 billion (World Bank, 2018). Although there have been extensive rehabilitation efforts by the Iraqi Government and international development agencies, a large proportion of Iraq's infrastructure remains either damaged or destroyed, directly impacting the volume, quality and reliability of water and other services delivered to households (UNICEF, 2016). Extensive leaks occur throughout the water supply network and the volume and quality of freshwater has declined steadily over many years due to drought and river inflows. Inadequate treatment has led to sewage being discharged directly into rivers. The chronic shortage of electricity compromises water system infrastructure even further, with unstable power supply and frequent outages lowering water production and distribution (*ibid.*).

8.2.2.5 Lack of investment required to maintain and expand water services

The total capital investment required to connect all households to the public water supply network was estimated at US$6.6 billion for the period from 2016 to 2025 (UNICEF, 2016), with inflation causing the per capita cost to triple since 2000. Conflict has compounded the challenges to improve the levels of water and wastewater services, with ISIS and the ensuing economic crisis having caused water projects either to stop or slow down, severely impacting any progress that had been made (World Bank, 2018).

To repair and reconstruct water systems after damage caused by direct attacks to those systems as part of the conflict requires enormous amounts of funding and effort (*ibid.*). The investment needed to develop urban water systems in Iraq in the first place takes decades of concerted action that focuses not only on infrastructure but also on sector strengthening and institution building (*ibid.*). Protracted emergencies, such as that in Iraq, typically attract low levels of funding, with funding levels often insufficient to fully rebuild destroyed infrastructure. Iraq's government and the World Bank estimated Iraq's total recovery and reconstruction needs at US$88 billion, which included US$ 2442 million for the WASH sector, across the directly affected governorates over five years (*ibid.*).

8.2.2.6 Institutional failures

Institutional failures have led to inefficient water use and unreliable water services in Iraq. The failure to create incentives to manage demand and implement effective tariff modalities throughout Iraq illustrates how water is undervalued in the

country. Iraq has one of the lowest water tariffs ($0.01 per cubic metre) in the MENA region and a high proportion of GDP is spent on public water subsidies (Human Rights Watch, 2019a, 2019b, 2019c; World Bank, 2018). With the ISIS conflict and economic crisis, accompanied by weak enforcement of water tariffs, revenues have fallen short of the levels required for infrastructure development and maintenance, including increased costs of abstraction and treatment. Most local and federal authorities have been reluctant to raise awareness of responsible water usage or the need to change people's water usage habits (World Bank, 2018).

Water services in Iraq are heavily centralised across governmental organisations. As there is no official water law, there is no official guidance to regulate the working mechanisms between these ministries. The segmentation of responsibilities for individual aspects of the water supply chain among five separate government departments and lack of coordination across government institutions has led to failures to address the complex water challenges in the country (UNICEF & UN HABITAT, 2013; Mumssen & Triche, 2017). Iraq's National Development Plan 2018–2022 (Ministry of Planning, 2018) has recommended establishing a 'National Water Council' to formalise the coordination mechanisms among relevant stakeholders in the water sector, in order to manage water resources at a national level and seek/oversee agreements at a transboundary level (*ibid.*).

Compounding the limited coordination amongst water sector institutions in Iraq is a lack of regulation relating to water supply. These two factors combine to impede the development and implementation of possible solutions for example smarter, targeted water tariffs or encouraging public–private partnerships, which could help build a more resilient water sector. Some of the main challenges facing the water sector in Iraq are outlined in Table 8.1, framed using IRC's 'building blocks' for a healthy WASH sector (Huston & Moriarty, 2018).

The role of the private sector in developing water and sanitation infrastructure, and in delivering and maintaining services, is limited in Iraq with investment in water services almost negligible. The private sector works with the local mayoralties to collect water tariffs and there are some private sector operations running small-to-medium-sized reverse osmosis (RO) water purification stations to supply water. However, the majority of these stations are unlicensed and unregulated and often the water quality does not comply with national drinking water standards.

8.3 THE SOLAR-POWERED WATER SYSTEM PROGRAMME

8.3.1 Programming for water scarcity in Iraq's WASH sector

The solar-powered water system programme was developed against a backdrop of broader strategic support which UNICEF has provided to Iraq's WASH sector.

Table 8.1 Challenges in Iraq's water sector.

Trend/Factor Impacting Adequate WASH Provision	WASH Sector 'Building Block' Impacted	Impact
Upstream riverine development (dams)	Water resource management	– Deterioration in water quantity downstream, largely in areas of southern Iraq
Climate change	Water resource management	– Reduced water availability (reduced rainfall and increased evapotranspiration/evaporation)
Increased water consumption	Planning	– Increasing deficit between available water resources and water demand
Deteriorating critical infrastructure	Infrastructure	– The extensive damage/destruction of WASH systems deeply affects their functionality in the cities and governorates, thereby affecting water services
Lack of proper funding	Finance	– Water projects are limited to operation and maintenance – Insufficient water and wastewater treatment – No new water projects are being planned or implemented – services are not extended or improved
Lack of long-term strategic plans and resilience approaches	Planning	– Failure to create incentives to address water scarcity across the country – Overlap of mandate and activities between ministries inhibits effective coordination
Poor water tariff structure and high subsidies	Policy and legislation	– Limited perception of the value of water, contributes to excessive and inefficient use – Limited revenue due to (a) the unwillingness of people to pay their water bills and (b) low tariff structure. Both of these inhibit the amount of maintenance which can be carried out, further compromising the quality and reliability of services
Limited role of private sector	Institutions	– Low investment and collaboration between the government and the private sector

Table 8.2 UNICEF-supported initiatives in Iraq's WASH.

Water Scarcity Responses	Detailed Interventions
Catchment water quality	• Strategy report on water quality management for Iraq
Demand management	• National Water Demand Management Plan, including water quality and wastewater treatment
Urban approaches	• Mobilisation on water conservation • Support to tariff frameworks and reducing non-revenue for water
Water supply enhancement	• Support to scale-up alternative technologies including reverse osmosis treatment, through public–private partnerships

UNICEF, alongside other sector partners, has worked with the Government of Iraq over a number of years to augment the water supply in the face of more complex and unpredictable threats through the development of strategic actions in sector planning and water management. This support has involved assisting government ministries to carry out assessments, identify and implement solutions and monitor their effectiveness. This approach has included considerations of catchment water quality, demand management, urban approaches and water supply enhancement, as set out in Table 8.2.

8.3.2 The intervention and local rationale

While UNICEF had already worked in cooperation with the local government water service provider in the northern governorates to rehabilitate the basic water systems and services in their coverage areas, challenges were faced to operate these rehabilitated systems. These challenges included unreliable power supplies (national grid and diesel generators), as well as a general lack of financial resources and qualified labour (Oxfam, 2018). In Iraq, water supply is generally powered by electricity from the local grid. The most vital link between critical water services relies on electrical power, provided by generating stations, distribution/transmission lines and substations, or, when a regular electricity supply is unavailable, on generators and fuel (*ibid.*; World Bank, 2018). A continuous electricity supply is required for all the components of the water supply systems to function; for example, water is moved throughout the distribution networks by pumped or gravity-fed systems, which requires electricity. Any attack on or shutdown of the electricity service (or generators and fuel) can disrupt water provision. Recent conflicts have seen many examples of attacks on elements of the electricity grid, leading to a loss of water supply. In

addition, grid electrical power is becoming increasingly unreliable due to the heavy load placed on it, particularly in the summer months when air conditioning places a significant additional load on the system. The overall effect is to reduce the reliability and operational capacity of electrical supply and therefore water supply systems (*ibid.*).

Solar-powered water supply systems were introduced as a more sustainable, low carbon, alternative which required less maintenance and skilled labour and was a viable solution to increase the access to, and reliability of, safe water services for the most vulnerable and hard-to-reach communities of Shekhan and Makhmur, while reducing demand on the electricity grid.

The reasons for the rapid expansion of solar-powered water systems are many, but primarily relate to their rapidly reducing installation costs (and ever improving efficiency), lower maintenance costs, increased reliability and resilience, as well as lower carbon impact, particularly where fossil fuels are used to power water supply – as in the case with Iraq.

The solar-powered systems were installed in Shekhan and Makhmur, two rural districts in the north of Iraq. Both districts include Syrian refugee camps and the host communities have also been profoundly affected by the ongoing conflict and reduced access to water services.

Both districts suffer from water shortages, usually caused by ageing water infrastructure and limited access to the public water networks. Much of the water supplied to these areas is through private sector water trucks, which deliver to homes with capacity tanks on a weekly or monthly basis. The boreholes from which these trucks extract water in these districts contain high levels of sulphate and nitrate, often making water unsafe to drink.

The influx of refugees and IDPs has placed additional pressures on water services in both districts. UNICEF has worked with the government to ease this pressure, increasing the number of water trucks and supplying additional tanks to store water in the camps. Such solutions are often used at the onset of an emergency. The situation in Iraq is one of protracted emergency, with the lifespan of some camps exceeding five years. The design, installation and operation of solar-powered systems with reverse osmosis aims to provide a longer-term solution.

8.3.3 Advantages of solar-powered systems over diesel generators

Diesel generators are typically used in Iraq to operate water pumps in boreholes as their installation costs are usually cheaper than solar systems and generate similar amounts of power. However, in many rural areas it is difficult to maintain a regular supply of diesel and strict health and safety regulations must be implemented when diesel is stored in large volumes. In recent years in Iraq, diesel power is seen less and less as a sustainable option for the operation of water systems, particularly compared to solar-powered alternatives (see Table 8.3).

Table 8.3 Solar-powered system compared to diesel-powered system.

	Solar-Powered System	Diesel Generator
Maintenance	Less maintenance required Long-term warranties Most future maintenance (after the warranty expiry) can be done at a low cost	Regular maintenance required by skilled workers Regular changes of oil and filters are needed
Operation	An operator checks the system periodically, as it is automated	An operator must be available to operate and stop the generator and conduct basic checks
Safety	Few hazards if the system is designed and installed properly (a protective fence around the solar panels is recommended)	Higher potential for accidents, including fires (requires a protective shelter due to fire and electrical power risks)
Power generation	Variable, depending on the characteristics of the local weather conditions	Constant
Environmental	Low carbon impact	Generates emissions that exacerbate climate change and can be very noisy
Resilience	The system is fully operated by solar power and is less affected by interruptions for example conflicts, fuel/spare part interruption	The diesel-powered pumps will not work if diesel supply is interrupted due to interruptions to fuel and spare parts

Solar-powered water systems are low carbon solutions. They can reduce greenhouse gas (GHG) emissions when chosen over either diesel generators or grid-based electricity to power water systems, particularly in a country such as Iraq, where grid-based electricity is almost entirely generated using fossil fuels. Extensive use of solar-powered water systems could therefore lead to substantial reduction in GHG emissions.

8.3.4 How the solar-powered water systems work

The systems which were installed consist of a number of elements. A submersible pump abstracts water from the borehole and pumps to a reverse osmosis (RO) system. The RO system treats the water by applying pressure to the water on one side of a selective membrane. The impurities are retained on the pressurised side and the clean water passes through to the other side. The water is subsequently stored in an elevated tank and treated using a chlorine injection unit. All of the system's electrical parts (pumps, RO and chlorine unit) are powered by solar panels (Figure 8.2).

8.3.5 Outcomes

In Shekhan, 102 solar panels produce 32 kilowatts (kWh) of power (at 0.315 kWh each). The submersible pump power rate is 15−22 kWh. The discharge capacity of the borehole is 28 m^3/h. The average daily provision of water from the solar-powered water system in Shekhan is 250 $m^3$and operates for 10 h in the summer without the need for supplemental power from the national grid or generator. On cloudy days during winter, the system produces 30% less energy on average. The systems have supplied at most, 20,000 people with reliable water supplies. They have increased access to safe drinking water, in excess of the minimum standards (100 litres per person per day), in these areas.

Figure 8.2 Solar-powered water project in Shekhan.

A comprehensive one-day training session has been provided to local government technicians on system maintenance and troubleshooting. The training was delivered immediately after completion of the system installation and was designed to support local capacity development and enhance closer coordination with the surrounding water directorate. UNICEF has also worked with the local water authorities to conduct water tests, to ensure the water is fully compliant with WHO drinking water quality standards. Furthermore, the project was handed over to the service provider at the local governorate who is responsible for operation and maintenance and all costs will be covered by the federal government financial budget location.

8.4 CHALLENGES AND OBSERVATIONS

While the project has been very successful in highlighting the potential of solar power for water supply services in Iraq, significant challenges were encountered.

A challenge was reallocating alternative land to implement the project due to local community and legal issues which became clear after the commencement of the project. Both challenges prolonged the project implementation period and highlighted the importance of clarifying the land ownership legal status in writing with all the relevant authorities and surrounding communities during the planning phase. In addition, it is important to clarify how national and/or local tax and customs regulation affects any necessary equipment importation well ahead of purchase.

UNICEF Iraq is planning to scale up the solar-powered system to further sites in rural areas in which disadvantaged populations are settled and are affected by variable quality of services. The aim will be to encourage sustainable and environmentally conscious power solutions in areas where the water authority has a limited capacity to operate water systems and where people cannot easily afford fuel to run generators.

UNICEF and the private sector will also make efforts to strengthen local markets and improve supply chains. Additionally, capacity building at all levels, particularly for local contractors and technicians, is vital to further professionalise the solar-powered water system management model.

After a year of operation, the systems have proved to be feasible and effective. There have been no shutdowns, resulting in considerable cost savings compared to diesel generators. The solar-powered water systems have provided a sustainable and reliable supply of safe water for hard-to-reach, vulnerable communities in Shekhan and Makhmur, while at the same time reducing air and noise pollution, emissions and operating costs.

The solar-powered water systems have produced sufficient water volumes and proven easier to operate and maintain than diesel-generator systems. This means they require less resources to keep them running and have the potential to offer a more sustainable solution for providing water systems to harder to reach, vulnerable communities.

8.5 CONCLUSIONS

The water crisis in Iraq is an urgent, complex, problem caused by numerous factors. It will require new, innovative, solutions and the development of water systems that are affordable, scalable, energy and water efficient and climate-smart. Solar-powered water systems have the potential to meet all of these criteria. However, solar systems, as with any motorised system, needs to ensure that current and future yields have been correctly estimated and that the systems are climate resilient and that water levels and quality are monitored.

To deliver solar systems successfully and sustainably across Iraq, further support will be required to strengthen the enabling environment (including oversight), build capacity, engage the private sector to strengthen local markets and improve supply chains.

Solar-powered water systems can be a more sustainable, reliable and low carbon way to supply water and can be a particularly effective solution for remote locations that are beyond the reach of the national grid network. Properly designed and maintained systems can help to alleviate the impacts of water scarcity in areas where access to water is a challenge and in regions where demand has risen quickly. It has also made an important switch from fossil fuels to renewable, clean energy sources has the potential to mitigate the negative effects of GHGs.

The results have shown that solar-powered water systems have performed well. They offer some potential to ensure greater resilience in the fragile, conflict-affected rural locations, where poverty levels are high and communities are greatly exposed to a range of threats, most significantly conflict and endemic water scarcity. The systems have ensured greater resilience in these communities, leaving them less dependent on fuel supply, which is frequently disrupted in Iraq. Despite this, investment in water services in rural Iraq is a long term, complex, endeavour. In this limited perspective, solar water systems may offer some resilience for the rural communities, where it is likely to take many decades for water services to have the necessary finances, human and technological capacity in place to deliver affordable and sustainable services for all.

The local governments' authorities at the governorates level need to be engaged to scale up such an initiative to provide water services to the most deprived population living in rural areas and suffer from unsustainable electrical power supply. Efforts should be made to ensure solar-powered technologies are made accessible and affordable for everyone. In terms of reaching the absolute poorest, this service delivery model should include the water price and include subsidies to support most marginalized households where required.

While solar-powered water systems require less resources to operate and maintain, it is nevertheless crucial to develop the capacities of both the public and private sectors, so that they can successfully install and manage systems, strengthen markets and improve accountability. Thus, UNICEF needs to continue advocating with the federal and local governments to invest more in

solar-powered systems and build public and private sector capacities to successfully install and manage systems, strengthen markets, and improve accountability. This is imperative if solar-powered systems and other water supply systems fully meet the needs of the communities they serve. If these improvements can be made, solar technology can provide a significant opportunity to achieve universal and sustainable water access for millions of people.

Using the experiences and lessons of this programme as a foundation, there is no doubt that solar technology has the potential to be one of the cornerstones to achieving sustainable access to water services for millions of people in rural, water scarce, environments.

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