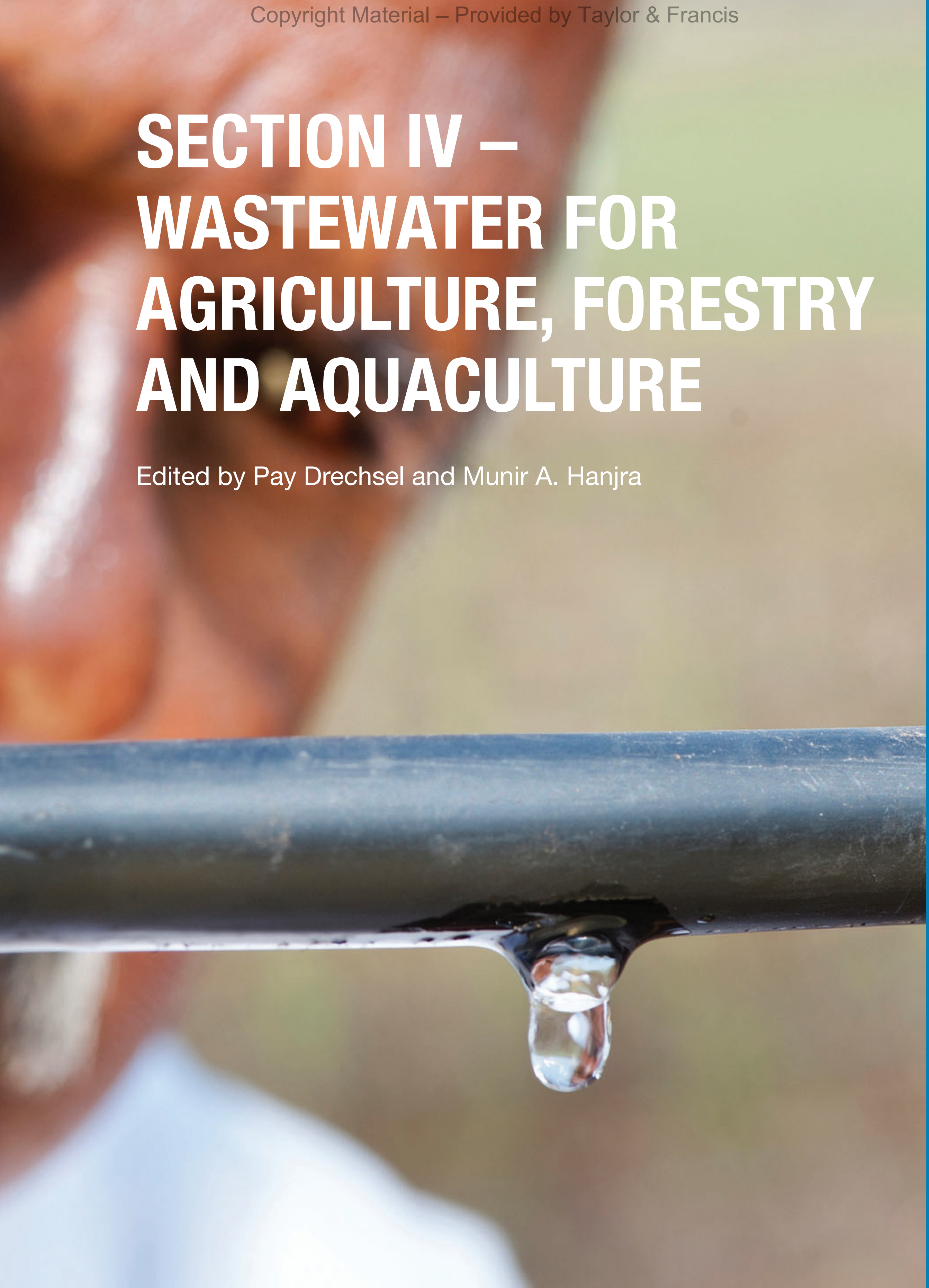


SECTION IV – WASTEWATER FOR AGRICULTURE, FORESTRY AND AQUACULTURE

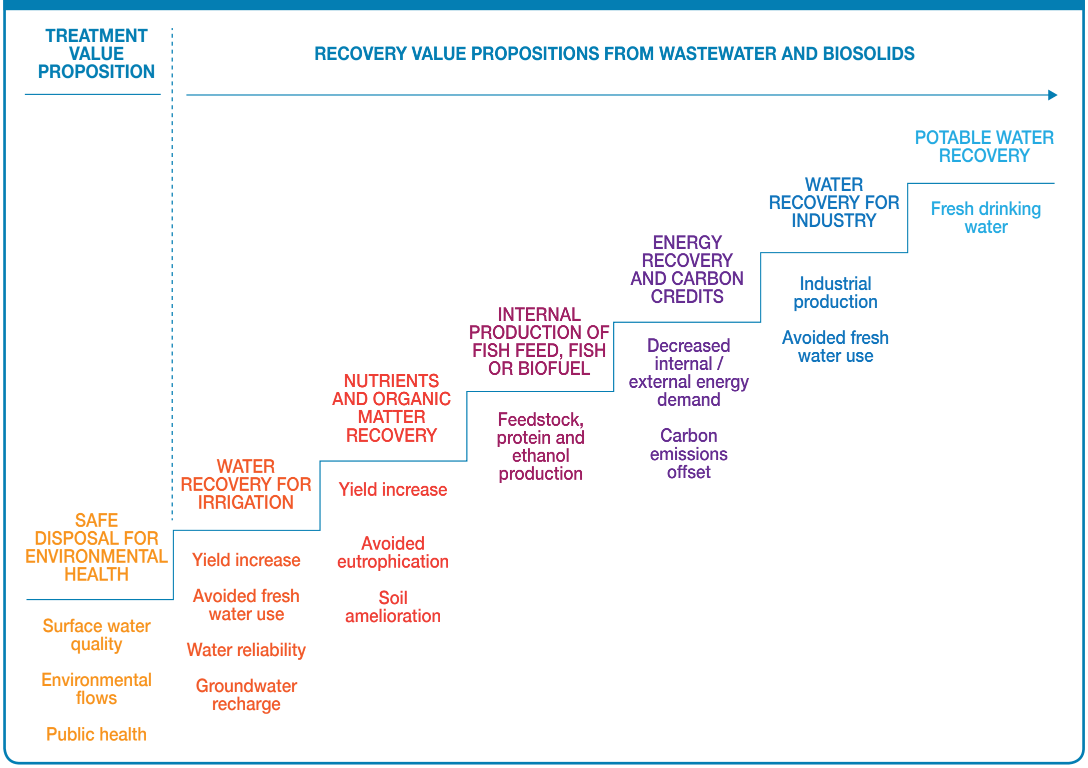
Edited by Pay Drechsel and Munir A. Hanjra

Photo: Hamish John Appleby/IWMI

Wastewater for agriculture, forestry and aquaculture: An overview of presented business cases and models

Between now and 2030, the sourcing of water for human needs is expected to change, as the pressure on natural freshwater resources becomes more intense. This pressure is likely to come primarily from agriculture, as increasing demands for higher protein diets and biofuels will require a significant increase in agricultural output, which can only be met through greater water use. This will accelerate the over-exploitation of our freshwater resources, including a 66% increase in non-renewable groundwater withdrawals which is likely to affect millions of people by 2030, and billions by the end of the century (GWI, 2014). Under these circumstances, there will be limited alternatives to water reuse and desalination, especially where long-distance transfer is not cost-competitive. As public agencies seek economically and socially acceptable solutions to cope with increasing water demands, matching waters of different qualities with appropriate uses and implementing helpful reuse incentives will become essential for achieving the Sustainable Development Goals 6.3, 7.2 and 12.5, which directly address resource recycling, recovery and reuse. Unfortunately, the wastewater sector has long been a neglected utility, driven by regulation rather than economics or business thinking. But the situation is changing and water reuse is gaining significant momentum in discussions around green economies, urban resilience and enhancing urban food security. The awareness is growing that wastewater is in fact the only source of additional water that is increasing with population growth and higher water consumption, offering a range of opportunities for transforming wastewater and bio-solids into value propositions (Figure 206).

FIGURE 206. LADDER OF INCREASING VALUE PROPOSITIONS RELATED TO WASTEWATER TREATMENT BASED ON INCREASING INVESTMENTS IN WATER QUALITY AND/OR THE REUSE VALUE CHAIN



Source: Drechsel et al., 2015.

The highest market growth has been forecasted by Global Water Intelligence (GWI, 2010) for advanced water treatment supporting high value industrial and potable use. GWI is predicting that despite higher treatment costs the returns on investment will be rewarding. Already today we see many examples, also in developing countries, where up to 100 % of the operational and maintenance (O&M) requirements can be met from the sale of treated wastewater to local industries for uses such as cooling, power generation or air-conditioning (WSP, 2016). Cost recovery is usually less promising in view of agricultural reuse. Although the agricultural demand might be much higher than from particular industries, the sector's willingness and ability to pay are usually much lower, especially in low-income countries, while demand is often seasonally limited. Also in regions with highly subsidized freshwater tariffs or free groundwater access, cost recovery potential is low (Hanjra et al., 2015).

Thus, many wastewater business models are mainly **social models**, which are economically strong but fall short in view of financial sustainability unless the societal benefits are internalized. A survey conducted, for example, by the Water Environmental Research Foundation showed that only 12 out of 79 projects setting reclaimed water rates, aimed at full cost recovery (GWI, 2010). In these cases, motivating the use of reclaimed water takes precedence over cost recovery. In a report by the Tunisian Ministry of Agriculture, cost recovery rates in different irrigation projects with treated wastewater ranged between 13% and 76% of operational expenses for the agricultural supply component only (Chenini et al., 2003), not including the operational costs of the treatment facility. This is because financing water reuse projects can be challenging in that it is often expensive to build and operate an additional set of pipes and pumps to reach the final users, unless investors take over the responsibility. A more interesting point is why do some projects manage 76% while others only 13%? Such differences can derive from the choice of technology, institutional set-up, value proposition and targeted investment in cost reduction and recovery as our examples will show.

The first example of **Business Model 16** was presented in the previous section, and showed how wastewater treatment plants can reduce their operational costs of unwanted phosphorus (P) removal by investing in its recovery. The model by the company Ostara has therefore been presented in the Nutrient Recovery section. The model can be combined with energy recovery as shown recently in Amersfoort, the Netherlands where a 12,000-ton sludge treatment installation at the local wastewater treatment plant was commissioned in 2016, that will annually produce 900 ton (t) P-rich struvite and has an energy surplus of 2 million kilowatt hours (kWh) that will be delivered to the national grid.

This wastewater section of the Resource Recovery from Waste catalogue starts by describing three water reuse projects from **Egypt, Tunisia** and **Morocco** in Chapter 14**.** They represent different plant sizes, and institutional and regulatory challenges, and can therefore stimulate discussion on how to best maximize social and environmental benefits while targeting cost savings and recovery through closed loop processes and the sale of, for example, forest products. The three cases are located in a region where water is a scarce resource and reclaimed water can be of high importance for different sectors including farming and afforestation, therefore providing the basis for **Business Model 17: Wastewater for greening the desert (Institutional and regulatory pathways to cost recovery).** A fourth related case is Jordan's As Samra plant. However, due to its interesting financial set-up, the case is presented separately (see below).

The potential for cost recovery or even profit is multiplied when costs are minimized and returns maximized. This is possible where treatment systems are low in energy consumption and the resource recovery and reuse (RRR) value proposition goes beyond simply recovering water to incorporate the next steps of the value chain by selling products (e.g. fish fed with fodder) grown with the nutrients wastewater offers. In such cases, the likelihood of recovering both the fixed and variable costs of

the (added) reuse component as well as the operational and maintenance costs of the treatment process can be substantial as the analyzed cases show. Technology choice is important, particularly in developing countries. Wastewater use in agriculture or aquaculture, can be supported through pond based treatment processes, with low investment costs and affordable operation and maintenance. Such processes are particularly suited to countries with warm climates where biological processes perform well. The investment costs for such locally 'appropriate' technologies are in the range of 20% to 50% of more conventional treatment plants, while the operation and maintenance costs are in the range of 5% to 25% of conventional (activated sludge) treatment plants (Libhaber and Orozco-Jaramillo, 2013). Chapter 15 presents two cases from **Bangladesh** and **Ghana** which show community based low-cost treatment systems in combination with the establishment of a fish-based value chain, taking advantage of the nutrient content of the wastewater. In the case of Bangladesh, the pond operator-cum-entrepreneur even recovered the construction costs of the treatment system. This is followed by an explanation of the overall model derived from the cases, which could potentially be applied to other settings – **Business Model 18: Leapfrogging the value chain**.

However, this business model does not imply that only smaller community-based pond systems can build on RRR to achieve high cost recovery. Many of the largest wastewater treatment plants in the world minimize their operational costs through highly efficient energy recovery mechanisms. As described in Chapter 16, **Jordan**'s extended As Samra wastewater treatment plant which was inaugurated in October 2015 is able to generate up to 95% of its energy needs, supported in part by a favorable topography. With minimized operational costs and an innovative overall cost sharing model, it contributes significantly to Jordan's entire renewable water resources, freeing up fresh water for more valuable uses. The main sources of finance for capital expenditure are public spending, external aid (loans, grants) and revenues from potable and industrial water use. The set-up of funding sources and guarantees can be of high complexity as shown in case of As Samra, but also much simpler as described for example by the Water and Sanitation Program (WSP) (2016) for Tamil Nadu. **Business Model 19: Enabling private sector investment in large-scale wastewater treatment** explains the institutional arrangements and overall characteristics for this type of model.

Energy recovery has also in smaller treatment plants the most significant potential for cost savings. While water and nutrient recovery can provide a certain contribution to offset the costs of sanitation and wastewater management systems, it is mostly the recovery of bioenergy that supports more substantial O&M savings. A survey carried out by WSP in India, for example, showed that energy recovery rates of 80–95% allowed to cut O&M cost of the studied wastewater treatment plants by half. The addition of a biogas plant, which costs about 15% of the wastewater treatment plants own capital cost, showed a pay-back period of only two to three years with an Internal Rate of Return of 33%. To support on-site electricity generation, contracts with private plant operators can be designed so that twice the amount for the power is charged whenever power is drawn from the grid to meet the plant's energy need and this is deducted from the payment made to the contractor (WSP, 2016). According to a 50-country analysis by Wang et al. (2015) bioenergy recovery has a high potential to realize environmental sustainability in developing countries where approaches should be customized, rather than attempting to replicate the successful models of developed countries.

Another set of interesting business models are emerging in the rural–urban interface. Growing urban water demands are placing substantial pressure on urban and peri-urban areas, leading to increasing calls for water reuse and integrated inter-sectoral water management and transfers. Chapter 17 covers four cases in this important interface: the rural-urban water-wastewater swaps in **Spain** and **Iran** (**Business Model 20: Inter-sectoral water exchange)**, and the cases of **India** and **Mexico** where urban wastewater refills peri-urban and rural aquifers. In these cases, peri-urban areas

function increasingly as 'kidneys' for the urban metabolism (**Business Model 21: Cities as their own downstream user**), which can be a promising model as long as possible environmental and human health risks are controlled, a statement which of course applies to all waste-based RRR models.

The last set of 'business models' differ from the others and are intended to stimulate further discussion. This is needed as wastewater reuse in agriculture is actually much more common than any official statistics so far have shown. The latest estimates indicate 36 million hectares of irrigated cropland depend on untreated or partially treated wastewater, used directly or indirectly after dilution (Thebo et al., 2017), in areas where urban treatment capacities are not keeping pace with population growth. The widespread use of unsafe water in these areas has prompted the World Health Organization (WHO) to test and recommend alternative on- and off-farm options for safeguarding farmers and public health, such as the multi-barrier approach (Drechsel et al., 2010). However, the adoption – or more precisely the provision of incentives for the adoption – of such safety measures remains a major challenge, and is urgently needed where regulations are not able to enforce measures such as crop restrictions in the informal irrigation sector. In support of WHO's sanitation safety planning concept (WHO, 2015) this catalogue presents three "business models" based on empirical cases from **Pakistan, India** and **Ghana**, supported by similar observations from other countries. The models are not mutually exclusive and show entry points and opportunities for increasing the safety of informal wastewater irrigation (**Business Model 22–24**) based on corporate social responsibility, the marketing of wastewater as a commodity and farmers' own investments in infrastructure, respectively. A model related to No. 23 and 24 with focus on improving the safety of informal (sludge) reuse was presented in the Nutrient Recovery section (Business Model 15).

In summary, most examples presented in the wastewater section of the *Resource Recovery from Waste* catalogue address the more common, but still complex and financially challenging situation of water reuse for agriculture, forestry and aquaculture, covering cases from Latin America, Africa, Asia and the Middle East and North African region. Several of the examples recover more than one resource and/or support more than the agricultural market. Further wastewater reuse examples from other sectors than agriculture have been covered elsewhere (e.g. 2030 WRG, 2013; Lazarova et al., 2013; USEPA, 2012).

A significant **weakness** throughout large parts of the wastewater section of the catalogue is the lack of reliable data on infrastructure financing or financial performance, as well as economic benefits. Extracting financial data from authorities or their publications posed a significant challenge, while economic impact assessments are generally rare. This is unfortunate, as internalizing the social and environmental benefits of wastewater treatment would probably well justify any public investments.

The presented cases and models – although by far not exhaustive – show a tremendous potential for RRR and private sector participation, where the enabling environment is in place (Chapter 19). If the well-known health and environmental risks can be controlled appropriately, there are many options to go beyond the social benefits of wastewater treatment and monetize the reuse value in ways that enable public and private sectors to achieve higher degrees of savings as well as cost recovery or even to generate profit. This 'double value proposition' will hopefully pave the way for a better delivery of wastewater services, and a more 'circular economy' for overall system sustainability (Andersson et al., 2016; Drechsel et al., 2015).

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14. BUSINESS MODELS ON INSTITUTIONAL AND REGULATORY PATHWAYS TO COST RECOVERY

Introduction

Most countries in the Middle East and Northern Africa (MENA) are severely affected by deforestation, or are simply too dry to sustain forests. Building green infrastructure (orchards, parks, green belts, forests, farms) in such a harsh environment can have substantial benefits for the ecosystem and society, especially if the investment does not compete for limited freshwater reserves but can build on 'waste' resources and even help avoiding disposal costs. In this context, there is no question about the multiple values wastewater treatment can offer society in dry climates on top of safeguarding public health. The three examples from Egypt, Tunisia and Morocco presented in this chapter were selected from a wide variety of similar cases. All three are located in water-scarce Northern Africa and show similar patterns and typical challenges of the region, as well as complementary features and innovations on the trajectory towards successful resource recovery and reuse (RRR). All three cases are aiming at **cost savings and cost recovery**, using RRR to create new revenue streams. Several other cases were explored but data availability did not allow adding more within the study period. A fourth case, however, could be Jordan's As Samra plant, which will be introduced in Chapter 16 as a model on its own (Business Model 19) due to its interesting financial set-up.

While in **Egypt**, the implementation of wastewater reuse is struggling with its institutional and regulatory set-up and missing incentives, significant progress can be reported from water reuse in afforestation and also in view of value creation from sludge, both with a huge potential for scaling up. The **Tunisian** example, on the other hand, showed the advantages of shared institutional responsibilities, private sector participation and a more flexible regulatory framework based on a strong political will to achieve environmental targets. The Tunisian example appears some steps ahead on the trajectory towards cost recovery although the case is struggling with its reuse percentages as many farmers can access alternative water sources with less stigma, risks and crop restrictions. In order to catch up, Egypt will have to revise its regulations and choice of crops to attract private sector participation for large-scale investment. Finally, the case study in **Morocco** shows how smart planning could allow achieving full cost recovery via decentralized, smaller systems for peri-urban communities. The setup of the case combined par excellence an applied low-cost technology, stakeholder participation, local resource recovery demands and a business plan for replication across towns and suburbs, with a dedicated accounting system to support full financial cost recovery. However, the potential of this setup received less attention after plant ownership and operations were transferred to the national sanitation agency. The progress and challenges in all these situations allow for the identification of possible bottlenecks and opportunities for new projects, and can help to steer the reuse agenda in view of SDG 6.3.

Following these case studies, the chapter presents **Business Model 17: Wastewater for greening the desert**, based on the country examples. It is relative flexible in its design and technical options as the main challenges appear to be vested in the (non-) supporting environment. After setup of a wastewater treatment facility, which follows in most cases the Build, Operate, Transfer (BOT) model supported by external loans, the plants could be managed by a public or private entity, with the same applying to the irrigation system. The Egyptian model of all components under one public sector company (in charge of sanitation) could allow to cut on transaction costs and improve cost recovery through the sale of wood, but can also be challenged by public sector inefficiencies and constraints, like overstaffing and limited entrepreneurial ambition, marketing knowledge and capacity. The Tunisian model with two governmental entities (sanitation and agriculture) working hand in hand for wastewater treatment and delivery to independent private water user associations combines complementary strength and expertise. If accompanied with a stakeholder dialog for participatory reuse planning, the model could be well positioned to thrive under different local conditions and crop demands (fruits, cotton, flowers, wood, etc.). The potential of such an approach is shown in the Moroccan

case. Depending on local needs and social acceptance, an alternative reuse model could be aquifer recharge as is increasingly supported in Tunisia. However, the key determinants in the analyzed cases are often in the regulatory context, institutional capacity and interests, and in the fiscal policy of the respective national government.

While the running costs of the treatment plants can be covered by household connection fees, especially if energy costs are kept low, appropriate freshwater pricing is needed to value wastewater. The value chain for farmers can be enhanced where reuse goes beyond primary production and supports for example protein generation via fish or fodder production for the dairy industry (see Business Model 18 on Leapfrogging the value chain).

CASE

Wastewater for fruit and wood production (Egypt)

Pay Drechsel and Munir A. Hanjra

Supporting case for Business Model 17	
Location:	El-Gabal El-Asfar, northeast Cairo, Egypt
Waste input type:	Domestic and small industrial wastewater
Value offer:	Secondary treated wastewater reuse for cactus fruits (70%), lemon trees, and wood production; sludge sale for composting and construction (cement mix)
Organization type:	Public
Status of organization:	Secondary treatment level operational since 1998, commercial reuse of lemons and cactus fruits since 2007 with breaks
Scale of businesses:	Treatment: medium (450,000m^3/day); Reuse: small 10,000 to 30,000m^3/day on max. 147 ha.
Major partners:	Holding Company for Water and Wastewater (HCWW) through (the Greater Cairo Sewage Water Company); Ministry of Water and Wastewater Utilities; Undersecretariat for Afforestation and Environment of the Ministry of Agriculture and Land Reclamation (MALR), Ministry of Water Resources and Irrigation; Other Ministries (Housing, Health), Desert Research Center

Executive summary

The Greater Cairo Sewage Water Company (GCSWC) operates the El Berka wastewater treatment plant in the north-eastern part of Greater Cairo. Although the bulk of its wastewater is discharged back into the environment, about 5% of its secondary treated wastewater is used for irrigating lemon trees, cactus and trees for wood production, such as Khaya senegalensis, and, on pilot basis, industrial oilseeds including Jojoba and Jatropha. In addition, about 1,500 tenant farmers renting government land use approximately another 12% of the treated wastewater to irrigate about 1,000 hectares (ha) to support their livelihoods. This activity is informal and no fees are charged. The majority of the entity's revenue comes from household wastewater fees levied on around 1 million connected households, helping achieve a high cost recovery for the treatment of the wastewater. However, only about half of the households pay regularly resulting in USD 3.6 million revenues. The plant also raises revenue of about USD 0.6 million from selling one third of the generated sludge for composting and to the construction sector. There is significant potential for expansion into the agroforestry sector which is

underused due to different challenges typical for the wastewater irrigation sector (not only) in Egypt. Therefore, compared with its potential, cost recovery through wastewater reuse is low, and the overall plant revenues subsidize the reuse system, in particular via household fees. This situation could be improved significantly with a change in the regulatory framework to support more progressive commercialization opportunities (choices of plants) and reuse standards, which is likely catalyzing private sector engagement.

KEY PERFORMANCE INDICATORS (AS OF 2014)

Land use:	42 ha for treatment plant, 210 ha available for afforestation of which so far only up to 30% were used					
Wastewater treated/reused:	0.4–0.5 million m³/day of which 10,000–30,000m³ are formally and 49,000m³ informally reused; 50–60,000t sludge produced per year of which 20,000t are sold.					
Capital investment:	48 million (discounted to 1990 prices) for treatment plant; USD 1.6 million for plantation and irrigation system					
Labor:	About 270 persons at treatment plant; 110 at the plantation					
O&M costs:	USD 3 million/year for the treatment plant; USD 0.6 million/year for the plantation (due to overstaffing) (2013)					
Output (revenue):	USD 3.65 million/year from household sanitation fees; USD 11,700–28,000/year from agroforestry system using 10,000–30,000 m³/day; USD 609,000/year from sludge sale (unpacked, packed, largely for cement mix)					
Potential social and/or environmental impact:	Employment creation through afforestation programs; public health and environment protection; forest (fruits), wood, oilseeds products; benefit of research and outreach in wastewater reuse in agroforestry systems					
Financial viability indicators:	Payback period:	Depends on tree growth rate	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Egypt has an arid climate with an annual precipitation in Cairo of only 26mm. The El Berka wastewater treatment plant and its wastewater reuse scheme is one of the smaller wastewater irrigated agroforestry plantations in Egypt. The total area allocated to the Holding Company for Water and Wastewater (HCWW) across Egypt for reuse is about 37,000 ha of which in 2013 about 4,622 ha were used. The El Berka wastewater treatment plant is managed by the Greater Cairo Sewage Water Company (GCSWC), a subsidiary company of HCWW. The plant is located in El-Gabal El-Asfar, in the north-east of Greater Cairo, in the Cairo Governorate, and employs about 270 permanent staff. Outputs from the secondary treatment (activated sludge) are sludge and water. While about 30% of the sludge is used for composting and cement production, only a minor part of the generated wastewater is formally used to irrigate fruits (lemons, cactus) and different wood producing trees (e.g. *Cupressus sempervirens*, *Kaya senegalensis*). At pilot scale oilseed/energy crops, like Jatropha and Jojoba, are being tested with promising results. The El Berka forest and horticulture plantation was established in 1998 by GCSWC and covers about 210 ha, of which so far 147 ha have been designed for irrigation offering jobs to 110 permanent employees at the plantation, 20 of them in support of irrigation. Since 2007, when lemon and cactus were commercialized for the first time, the actual area under irrigation varied between 21 and 60 ha.

The water is pumped from the treatment plant to the land parcels and a drip irrigation system is installed for the wood trees (wastewater only), whereas lemon and cactus receive both wastewater and freshwater via flood irrigation. The daily consumption of treated wastewater within the plantation

varied over the last years between approximately 10,000 and 30,000m^3, while farmers outside the plantation use informally about 49,000m^3. The variation in land area and water consumption were due to restriction placed on the sale of crops. After a successful production in the first years (2007–2010) the Ministry of Agriculture prohibited the commercialization of (already produced) products irrigated with treated wastewater in 2011 and 2012, while in 2013 commercialization was allowed with restrictions which led to a decrease in the managed production area. Efforts to harmonize and standardize regulations on wastewater use in agriculture culminated in the Egyptian Code for the Reuse of treated Wastewater in Agriculture (ECP 501/2005) by the Ministry of Housing, Utilities, and New Communities. These standards set in 2005 reference the 1989 WHO guidelines, not the updated 2006 revision and are considered as too strict especially in terms of crop choices for commercialization. Additional difficulties occur through lacking standards for laboratory analyses (different methods result in different values). Thus, although the reuse potential for land reclamation is high and there are many profitable cropping options, so far the legal framework and its dynamic is not attracting investors and requires substantial improvements (Soulie, 2013).

Next to land reclamation and productive reuse, another driver for water reuse is operational risk reduction. Discharging wastewater to the Nile, canals or drains are controlled by law through licensing which requires compliance with set discharge standards. Failure to comply can mean withdrawal of the licence; however, there is hardly any source control.

Market environment

The public Holding Company of Water and Wastewater (HCWW), established in 2004, owns all water and sanitation infrastructure in Egypt. It works through its 26 affiliated subsidiaries companies across all Egyptian governorates where its 126,000 employees serve 85 million citizens. In 2013, HCWW operated 2,690 water treatment plants, and 357 wastewater treatment plants in the country, with 80% of the latter providing secondary treatment. Today, Egypt produces about 7.6 billion m^3 wastewater per year, of which 3.8 billion are treated and about 0.7 billion formally reused (Abdel Wahaab, 2014). As regulations are difficult to enforce in the informal sector, direct and indirect use of (treated and untreated) wastewater is common.

Reuse in forestry systems is permitted by law and has been widely promoted by the government. According to HCWW around 63 man-made forests irrigated with treated wastewater occupy 4,622 ha. The total allocated land to HCWW (only) for reuse is about 37,000 ha which is about half of the size of all public and private forest plantations in Egypt. So far most plantations involving wastewater reuse have been government-driven. The government's support for private sector participation in water supply and sanitation did not go much beyond build-operate-transfer (BOT) arrangements for wastewater treatment plants. To stimulate wastewater use, Egypt and other countries in Middle East and North Africa (MENA) adopted a low-pricing policy for reclaimed water. As in addition freshwater use is subsidized, also for irrigation, it is most common to set a price for treated wastewater below the price of freshwater, in order to increase its market share. Thus, cost recovery via the sale of wastewater is far from being a viable option. In fact, thus far the rule is that water is provided for free to the plantations. The generally low water tariff rates lead to overconsumption and wasteful practices. Water consumed by Egyptian citizens, as measured by litres per capita, exceeds international rates, e.g. in the EU by a wide margin (USAID, 2013).

Free supply of treated wastewater is a significant loss for those treatment plants where the plantation is run by a different entity like the Undersecretariat for Afforestation and Environmental Affairs. In plantations run by the same operator as the treatment plant, like in the case of El Berka, reuse offers at least some value creation to extend the revenue stream beyond household fees and sludge sale. In

2009, dried sewage sludge produced in El Berka was directly sold to farmers with a gate price of USD 8.20/m^3. In other plants, HCWW sells the produced sludge to contractors for (on average) USD 6.1/m^3 and the contractors sell it to farmers with a profit margin. Other organic fertilizer in the Egyptian market are sold at about USD 17.76/m^3 (Ghazy et al., 2009).

Little information is available about demand for plantation products. Market assessments and marketing strategies are urgently required. Rotational forest production and harvesting schemes are so far missing, but it is assumed that the market for fruits, industrial oil and wood is significant. However, several plantations show very inhomogeneous wood production and commercialisation to major wood manufacturing companies for wood chips, wood fibre or board production is doubtable, unless wood quality (i.e. plantation management) is improved and overall production is increased. Sale of carbon credits generated due to the increased carbon sink effect in biomass and accumulation of organic matter in the soil have not yet been explored (Becker et al., 2013).

Macro-economic environment

Egypt, like other MENA countries, offers great opportunities for large-scale afforestation projects due to the availability of significant amounts of sewage water and wide areas of desert land. Given the lack of any substantial natural forests, aggressive desertification and the dependency of the national wood industry on imported raw materials, the productive reuse would serve multiple benefits for society and nature, and help the national wood industry. Following basic treatment, sewage water can be efficiently used as a resource for the production of wood, woody biomass and biofuel crops. The HCWW supports this vision through its 25 subsidiary companies, plans to stronger encourage private sector investments in reuse projects via tenders and to establish an affiliated company dedicated to the management and operation of wastewater reuse projects. While the production of edible and non-edible crops is in line with the Egyptian Code for the Reuse of treated Wastewater in Agriculture (ECP 501/2005), adjustments are in discussion to support stronger the cultivation of industrial crops, like cotton, and selected edible crops that are not eaten raw (Abdel Wahaab, 2014).

The Egyptian Water Regulatory Agency estimates the degree of overall cost recovery in 2012–2013 at 62%, and the recovery of operation and maintenance costs excluding depreciation at 76%. Although low water fees deprive treated water from its potential value, the free water supply to plantations supports their cost recovery potential. However, until now private sector participation in plantations is missing. Challenges are complex institutional arrangements with inadequate communication and coordination among authorities; unclear regulations for commercialization, land ownership issues and limited initiation of public participation in reuse to promote its value. Efforts have been made to establish a new policy to sell or lease desert land adjacent to wastewater treatment plants to private investors for forest plantations (Loutfy, 2011).

Business model

The value proposition is to create commercial and amenity value by turning desert soils with the help of secondary treated wastewater into a plantation for the commercial production of wood and fruits (Figure 207). This transformation entails significant economic benefits for nature and society if it can be replicated across all 350 to 370 wastewater treatment plants operated under the umbrella of HCWW (reduced wastewater discharge into other water bodies, reduced dependency on wood import, wind breaks/microclimate improvement, carbon sink, fresh water savings, employment, etc.) given the lack of any natural forests in the country.

Key factors in support of this proposition are full government support, the advantages of a central coordination (HCWW) and that the required land and water inputs are free. However, the already

FIGURE 207. BUSINESS MODEL CANVAS FROM THE OPERATORS' PERSPECTIVE (HCWW/GCSWC IN EL BERKA)

KEY PARTNERS

- Ministry of Water and Wastewater Utilities
- Under Secretariat for Afforestation
- Ministry of Water Resources and Irrigation
- Egyptian Environmental Affairs Agency
- Farmers (informal use)
- Connected urban households

KEY ACTIVITIES

- Collection and treatment of wastewater for safe water and sludge reuse or disposal
- Plantation management and sale of fruits and wood
- Collection of fees

KEY RESOURCES

- Wastewater and sludge, land and labor
- Expertise in irrigation and plantation management
- Capital investment

VALUE PROPOSITIONS

- To transform wastewater and sludge into safe products for reuse in agro-forestry, cement production and safe environmental disposal

CUSTOMER RELATIONSHIPS

- Government to government contracts
- Government to private sector contracts
- Automated system for tariff payment to the Gov./HCWW

CHANNELS

- Tender for reuse
- Water via pipeline
- Wood via direct delivery or collection at plant/plantation
- Fees via online payment (Cairo)

CUSTOMER SEGMENTS

- Wood and cement industry
- Fruit market

Under discussion:

- Cotton market
- Industrial oil market
- Biofuel market
- Export market

COST STRUCTURE

- Treatment plant OPEX, CAPEX
- Agroforestry system labor and machinery
- Opportunity costs of idle reuse capacity
- Customer service and fee collection

REVENUE STREAMS

- Household wastewater fees (via water bill)
- Sale of sludge for compost and construction
- Sale of fruits, wood and potentially other plant products
- Sale of wastewater to informal reuse sector (potential)
- Governmental subsidy; carbon credits (potential)

SOCIAL & ENVIRONMENTAL COSTS

- Possible long-term risk for groundwater but limited costs if safety protocols are followed

SOCIAL & ENVIRONMENTAL BENEFITS

- Reduced water pollution from wastewater disposal into streams
- Creating forest and farmland from desert
- Microclimate benefits; carbon sequestration
- Reduced dependence on wood imports and freshwater resources
- Employment and amenity values

installed reuse systems, like at El Berka, operate significantly under capacity in terms of planted land, used water, marketing and actual sale volumes, while staffing reflects design capacity, resulting in high operational costs and negligible revenues. A key reason for the mismatch relates to insecurity in the choice of crops which can be commercialized under the governing regulatory framework and other, mostly institutional challenges. This insecurity translates into scaling back in the planted area, limited investments in forest management (sustainable planting-harvest rotations) and across similar locations lack of private sector engagement.

The revenues to cover the expenditures of the afforestation efforts come from the sewer surcharges on the water bill, with some additional revenues from the sale of sludge. The overall El Berka treatment plant including the plantation achieved according to FAO (2014) a 119% operational cost recovery despite the fact that only half of all connected households pay regularly the billed fees. USAID (2013) estimated for the operating GCSWC a more conservative 79% on O&M.

The business concept would gain momentum by revisiting the regulatory framework and institutions in charge, to avoid that whole harvests get lost, engagement in an annual planting/harvest cycle, increasing the cropped plantation area (and returns per paid staff), improving collection rates from households and the consideration of charging those 1,500 tenant farmers who are informally abstracting a large volume of treated wastewater from the El Berka drainage channels. The charges could be levied as part of the Governmental land rent while offering farmers extension services, e.g. on how to comply with the safety code 501/2005.

Other revenue streams, once available, could be carbon or biodiversity credits. Given the social dimension of this business model the level of governmental support could be supported based on an evaluation of the provided economic benefits in terms of ecosystem services.

Value chain and position

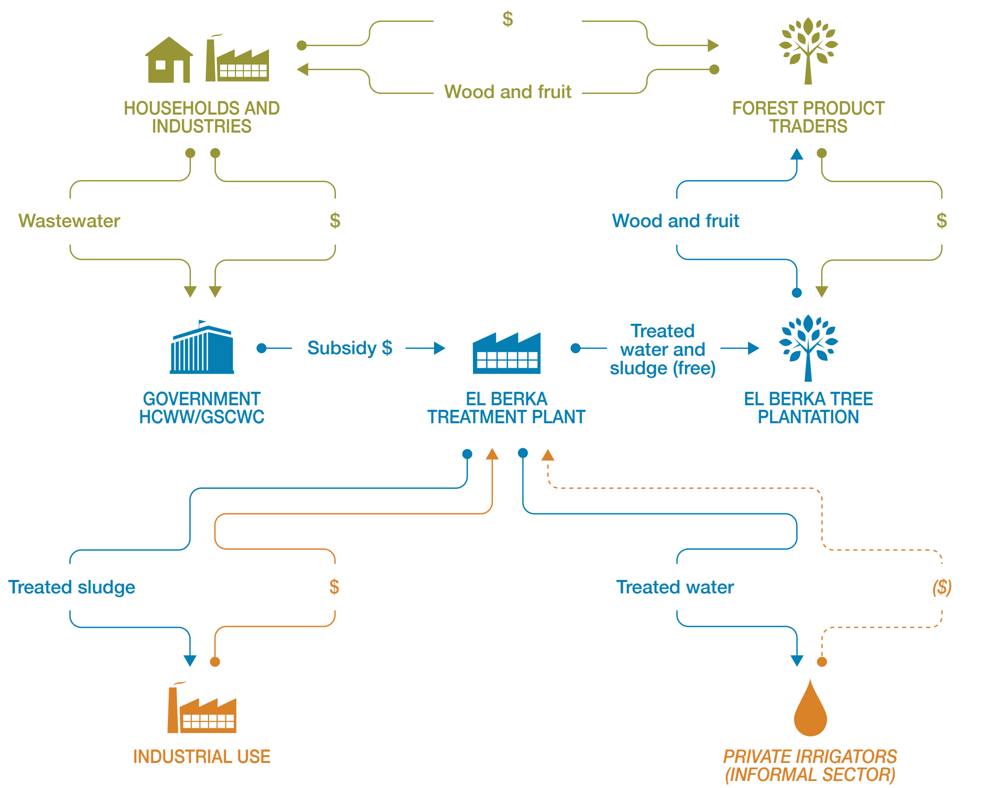
The main revenue streams are wastewater fees and additional governmental support (Figure 208). While the wood value chain in Egypt depends on import from Northern Europe and sub-Saharan Africa, this does not automatically make irrigated local forest plantations an attractive venture, especially not for private sector engagement due to the long growing time needed before the first harvest and returns on investments. A major initiative of HCWW is therefore to support the revision of the Egyptian Code for reuse to allow for the cultivation of industrial crops and some edible crops that are not eaten raw but have a significant market value, like cotton, industrial oil plants or biofuel and allow quick returns on investment (Abdel Wahaab, 2014). Growing such plants can reduce private sector risks, allows to diversify production and bridge till the first tree rotation after 13 years is on (FAO, 2014). The long initial waiting period is also risky for private sector investments considering the reform-friendly institutional landscape and related insecurities that policies might change over time to their disadvantage.

Companies in charge of drinking water and sanitation (like HCWW) are not mandated to set the tariff structure for the services they provide. It is the State which approves rates according to socio-economic and political criteria. This results in low prices that do not cover the cost of the service or the operation of these organizations in the majority of cases. There are continuing efforts to work towards a tariff policy and reform package, in support of an improved financial performance of the sector.

Institutional environment

The water and sanitation sector of Egypt went over the last decades through a series of institutional reforms.[1] Given the common water scarcity and the fact that the agricultural sector is the highest freshwater consumer, utilizing about 86% of the available supplies, water reuse, especially in

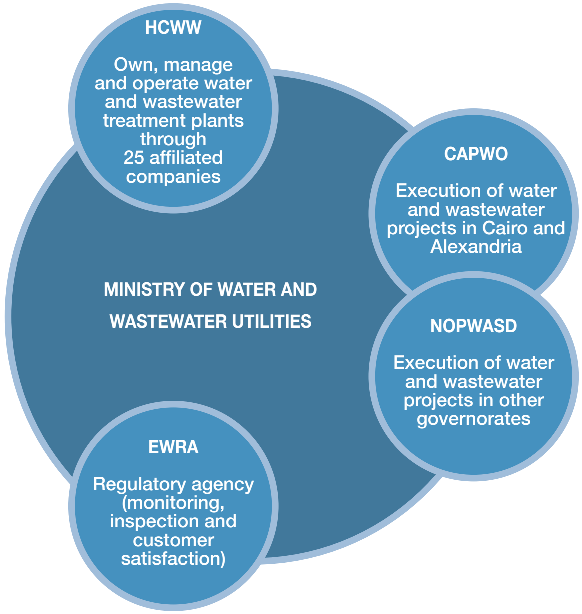
FIGURE 208. BUSINESS PROCESS FLOW OF THE EL BERKA WASTEWATER AND AGROFORESTRY SYSTEM UNDER COMMON OWNERSHIP



agriculture, was always part of the agenda. Laws and decrees have been issued including guidelines for mixing drainage water with fresh water, regulations for sewage and industrial effluents, wastewater reuse, cropping patterns, and health protection measures and standards specifications. The most important one is the Egyptian Code for the Reuse of Treated Wastewater in Agriculture (501/2005) by the Ministry of Housing Utilities and New Communities (Abdel Wahaab, 2014). There are at least five to six ministries with different roles involved in the wastewater management and reuse in Egypt. To streamline the institutional landscape the 2004 established HCWW owns, manages and operates all wastewater treatment plants across Egypt through its about 25 subsidiary companies. Other public companies under the 2012 created Ministry of Water and Wastewater Utilities (MWWU)[1] are the Cairo and Alexandria Potable Water Authority (CAPWO), which is responsible for the execution of water and wastewater projects in Cairo and Alexandria, the National Organization for Potable Water and Sanitary Drainage (NOPWASD) in charge of the execution of water and wastewater projects in other Governorates, and the Egyptian Water Regulatory Agency (EWRA) as an independent body of the others in charge of monitoring, inspection and customer satisfaction (Figure 209). However, due to overlapping responsibilities the regulatory agency remains so far relatively weak.

Besides the MWWU, several other ministries and institutes are involved in the wastewater activities. The Ministry of Agriculture and Land Reclamation (MALR) manages agricultural aspects, especially it operates forest plantations on reclaimed desert lands via the Undersecretariat of Afforestation and

FIGURE 209. INSTITUTIONAL ARRANGEMENTS UNDER THE MINISTRY OF WATER AND WASTEWATER UTILITIES



Source: Abdel Wahaab, 2013.

Environment (UAE) as its subsidiary body. MWWU took over function from the Ministry of Housing Utilities and Urban Communities (MHUUC), which was concerned with the planning and construction of municipal wastewater treatment plants.

The Ministry of Health and Population (MHP) assumes responsibility for sampling and analysis of all wastewater effluents. It is also responsible for setting water and wastewater quality standards and regulations in addition to its central role as the custodian of public health. The Ministry of Water Resources and Irrigation (MWRI) allocates water for reclamation areas and is responsible for the Nile. The Ministry of State for Environmental Affairs (MSEA) and the Egyptian Environmental Affairs Agency (EEAA) cater to environmental aspects (FAO, 2014).[2] Other stakeholders are scientific institutions and universities conducting basic and applied research activities and international partners (USAID, AfDB, GIZ, EU, etc.) supporting the sector (Abdel Wahaab and Mohy El-Din, 2013).

However, lack of communication and coordination among the authorities, overstaffing and overlapping institutional responsibilities, strict regulations for reuse, but only enforced in formal, not informal, systems, are some of the recurrent issues challenging progress (Abdel Wahaab and Mohy El-Din, 2013). While the ongoing reforms addressed major issues, others remain unresolved. For example, sector fragmentation was not actually reduced. No organization was dissolved; instead several new organizations were created. Cost recovery is still very low; overstaffing has apparently even increased, and the institutional separation of responsibilities for investment and operation remains a challenge, also for foreign assistance.

Technology and processes

Water: The wastewater treatment plant at El Berka was realized in two steps. The primary treatment was constructed in the year 1990. Facilities for secondary treatment were established in 1998. The plant has a total area of 42 ha and receives the wastewater from the 5 million people (1 million households) in the northeast Cairo through a specific sewer system. The treatment is biological and activated sludge in the aerated basins. An additional chlorine treatment is used to limit microbial contamination and potential disease risks for people and animals. While chemical characteristics of the treated wastewater were reported within the acceptable range for reuse with beneficial crop nutrient levels, microbial and parasitic data indicate that chlorination levels might be too low and do not reduce viable nematode numbers (Abd El Lateef et al., 2006). Consequently, additional safety measures are recommended where the water is used informally for crops eaten unwashed or raw. Groundwater levels are between 15–17m in the study area and an impact from irrigation difficult to verify (Abd El Lateef et al., 2006).

The treated wastewater arrives at the plantation from the treatment plant by gravity and by electric pumps. The water is pumped to the parcels and a drip irrigation system is installed for the wood trees, whereas flood irrigation is used for lemon trees and for cactus. The lemon trees and the cactus plants are irrigated both with treated wastewater and fresh water, whereas the wood trees are irrigated only with treated wastewater.

The plantation size is very small given the treatment capacity and there is a strong call for better matched systems, where decentralized, smaller wastewater treatment facilities allow to reuse a larger proportion of the treated water for agro-forestry than in large-scale facilities where the majority is discharged into receiving water bodies.

A particular challenge is the lack of controls to monitor wastewater discharge. This situation is untenable to a public private partnership (PPP) investor/contractor who is subject to a significant risk due to the practices of upstream dischargers that could easily compromise with toxic effluents the ability of a treatment plant to satisfy contractual obligations related to the quality of the plant effluent (USAID, 2013). There is a need to treat industrial wastewater separately and/or before discharge onto public sewer networks.

Sludge from the activate sludge treatment is dewatered in a gravity thickener and then sun dried. While its chemical characteristics were found acceptable (Ghazy et al., 2009), pathogen levels are natural high. To destroy pathogens a mixture of the sludge and agricultural waste (e.g. rice straw) are air composted where the temperature reaches about 65°C. The composted product is then sold as organic fertilizer for landscaping or for construction (to be mixed with cement). A limitation of the project is the expensive cost of rice straw (Massoud, 2010). The untreated sludge is discharged in desert areas.

Energy: For the replication of the system lessons from the neighbouring El Gabal El Asfar treatment plant will be useful where methane from the anaerobic digestion of sludge allows to produce 37–68% of the total power consumption for the treatment plant (Ghazy et al., 2009; Massoud, 2010).

Funding and financial outlook

Both the reliable supply of **wastewater** of suitable quality as well as vast areas of land are freely available for reuse. Although soil quality is poor, there are large volumes of nutrient rich organic (sludge) compost in direct proximity. Several trees and agro-industrial crops species showed good performance under the given climatic conditions. Thus, there should not be any biophysical problem to establish agro-forestry plantations. That so far most agroforestry schemes in Egypt operate

sub-optimally and current irrigated areas are far below the areas actually planned and/or equipped for irrigation has man-made reasons which can be addressed. So far only a small fraction of treated wastewater is reused, also in the El Berka agroforestry systems and the bulk is being discharged amid some informal reuse by crop farmers, yet no wastewater reuse charges are levied either on land rent or as reuse fees, which could offer additional revenues.

The main source of cost recovery are the household sanitation fees charged with the water bill. Given that only every second household pays as required, and the tariffs are far too low, adjusting the tariffs and increasing fee collection provide the largest opportunity for exceeding cost recovery while subsidizing any further expansion of the plantation (FAO, 2014). Higher freshwater tariffs could also stimulate demand for lower priced reclaimed water. On the other hand, if the plantation is supposed to be run by a third party, low wastewater tariffs will support investments. More important is in this case that the regulatory framework supports the commercialization of short-rotation crops with high market value, including export markets, allowing the operator to have diverse income sources and returns on investment before the first tree rotation is due. With such measures and annual planting/harvesting cycles the prospects of business viability are high.

The use of **sewage sludge** in landscaping and forestry should be part of the model as plants need organic matter and nutrients. According to the Egyptian Government future plan, there is the possibility that the El Berka composting project may be expanded to a full-scale project to produce a compost of 720 tons per day from the dried sewage sludge accumulated from El Berka, Shobera and Al Gabel Asfer WWTPs (Ghazy et al., 2009). Such a significant sludge production supports the Egyptian policy to reclaim land lost due to desertification. The extensive sunshine exposure, high temperature, and dry conditions provide aggressive and unfavorable conditions for the survival of microbial pathogens. Chemical risks can be limited by industrial source treatment and sludge reuse for non-edible crops. Moreover, the high pH of most soils limits crop uptake of heavy metals. Indeed, most soils in Egypt would benefit from sludge compost, as reclaimed land is usually poor in micro-nutrients, such as zinc and copper which are required for plant growth and present in sludge (Ghazy et al., 2009). The theoretical calculated monetary value of the dried sewage sludge in Egypt is about USD 53/ton (USD 28.5/m^3). This value probably indicates the maximum price of the dried sewage sludge that can be paid by farmers, including the transport costs in the Egyptian market (Ghazy et al., 2009). Where sludge quality does not match safety standards, other reuse options exist. The El Amria Cement Company in Alexandria has been granted EEAA approval for use of substitute fuel to natural gas in the cement kiln including hazardous waste. The proposed project is to use part of the dried and dewatered sludge produced from the wastewater treatment plants in Alexandria as substitute fuel in the cement kilns. This will reduce GHG emissions generated from the anaerobic conditions if sludge is disposed in the landfill. Moreover, incineration of this type of bio-fuel will produce less CO_2 emissions if compared to fossil fuel. Therefore, there is a possibility that this project can be considered as a potential clean development mechanism (CDM) project; which offers interesting perspectives for other plants in Egypt (Massoud, 2010).

Socio-economic, health and environmental impact

An environmental and social impact assessment carried out by the African Development Bank for the extension of the El-Gabal El-Asfar wastewater treatment plant with comparable treatment quality and draining into the same water resources as El Berka confirmed an overall positive impact of the plant on its social and ecological environment (AfDB, 2008). The wastewater and sludge reuse activities, if done at scale, are reducing in addition their unproductive discharge into the environment while creating employment opportunities. These like other benefits for land reclamation, the support of the local wood or cement industry, micro-climatic improvements and carbon sequestration will depend on the scale

of the water reuse and afforestation activities. The largest socio-economic and environmental benefit of reuse is its contribution to addressing water scarcity of communities across Egypt in the face of rising demand and shrinking freshwater volumes. The strict reuse standards provide less flexibility than the current WHO guidelines and Sanitation Safety Plans and could be adjusted, especially in formal reuse schemes where compliance monitoring is feasible. Efforts have to be increased, however, to address informal wastewater reuse by farmers outside the plantations where crop restrictions are not enforced. There are signs of microbial soil and groundwater contamination and a need for monitoring if and how far the irrigation is affecting the 15m deep groundwater table (Abd El Lateef et al., 2006).

Scalability and replicability considerations

The key drivers for the success of the reuse model are:

- Government's financial support for water, land and sludge use.
- Vast amounts of available resources, including a reliable water supply.
- Political will to further transform the sector.

The key obstacles are of institutional and regulatory nature:

- Limited private sector interest due to a too firm wastewater reuse code especially in terms of crop restriction.
- Overlapping responsibilities and limited cooperation among ministries and agencies in view of reuse and crop commercialization.
- Operational risk due to continuing sector reforms and reorganization with changing mandates and responsibilities.

Once the obstacles have been addressed, the El Berka model has significant potential for replication at decentralized level where land is available and forest plantations have a notable economic and social value for the local communities. Governmental support for initial capital cost will remain instrumental, both for the treatment systems and agroforestry system. However, cost recovery for the plantation is feasible. It can be run by the treatment facility or a third party. Product diversity with different payback intervals will be crucial while tapping into the emerging CDM market could be an additional option (Becker et al., 2013).

To support investments in reuse, HCWW embarked on an initiative to revise the Egyptian code for reuse to allow use of treated wastewater for cultivation of industrial crops and some edible crops that are not eaten raw, taking into consideration the required health protection measures. Ideally, a National Plan of Wastewater Reuse has to be established making freshwater use an exception where reclaimed wastewater is available, and where no reclaimed water is available, the freshwater tariffs have to be increased to stimulate wastewater (treatment for) reuse. However, since the Arab Spring residential tariff increases have become even more difficult to approve.

Summary assessment – SWOT analysis

Figure 210 presents the SWOT analysis of this business case from the reuse in agroforestry perspective. The case shows a high potential where resource supply and demand are in place but the institutional and regulatory environment prevents public and private sectors to make optimal use of the given opportunity.

FIGURE 210. SWOT ANALYSIS FOR EL BERKA WASTEWATER AND AGROFORESTRY SYSTEM

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Vast land and wastewater resources at low cost or free ▪ Strong vision of HCWW to support reforms for private sector engagement and increased cost recovery ▪ Wastewater quality matching reuse for forestry and species mix ▪ Location with limited risk of negative trade-offs ▪ Highly trained staff in place	**WEAKNESSES** ▪ Severe overstaffing due to scaling back of production ▪ Unclear and complex decision making regarding what can be planted and commercialized ▪ Unclear standards for laboratory analyses to comply with water and sludge standards ▪ Treatment quality can vary and monitoring is weak ▪ Also groundwater quality needs monitoring
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Revised regulatory framework allowing more non-edible products for commercialization ▪ Up-scaling of El Berka to design capacity and replication of similar plantations via decentralized smaller treatment plants ▪ WHO 2015 Sanitation Safety Planning concept facilitating compliance monitoring ▪ Export market ▪ Large national and export demand for wood which will support cost recovery	**THREATS** ▪ Mixed messages from authorities due to overlapping competencies ▪ Too restrictive regulations for cash crops which allow fast returns on investment ▪ Delay of reforms of regulatory framework and standards ▪ Negative public attitude and concerns related to product safety ▪ Fear of second Arab Spring preventing water tariff increase

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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014/15. As business operations and institutional environments are dynamic data can be subject to change.

Notes

1 Also called Ministry of Water Supply and Sanitation Facilities.

2 The names of institutions and ministries and their responsibilities changed frequently in the past and can change again.

CASE

Wastewater and biosolids for fruit trees (Tunisia)

Pay Drechsel and Munir A. Hanjra

Supporting case for Business Model 17	
Location:	Ouardanine near Monastir, Tunisia
Waste input type:	Domestic wastewater
Value offer:	Secondary treated wastewater sold for reuse in farmer-managed tree crop system (peaches, olives, grapes, grenades)
Organization type:	Public-private
Status of organization:	Plant set up in 1993, irrigation scheme operational since 1997
Scale of businesses:	Small: 1,590m^3/day treatment; reuse on 65–75 ha
Major partners:	National Sanitation Utility (ONAS); Regional Offices of Agriculture Development (CRDA); Groups of Agricultural Development (GDA) and local farmers

Executive summary

The National Sanitation Utility (ONAS) is a public institution in charge of the Tunisian sanitation sector and operates the small Ouardanine wastewater treatment plant near Monastir city (328mm annual rainfall), treating mostly domestic (non-industrial) wastewater from about 3,400 households. About a quarter of the reclaimed water is used by the nearby Ouardanine tree plantations (65–75 ha), managed by about 40–46 private farmers to produce olives, peaches and pomegranates to sell at the local market. In the case of irrigation, the downstream infrastructure is managed by the Governmental Commissariat Régional de Développement Agricole (CRDA), which receives the water from ONAS free of charge and is responsible for distributing and billing reclaimed water to end users (farmers' collectives or Water User Associations called Groupement de Développement Agricole; GDA). CRDAs charge the GDA a subsidized water price which is fixed by the government as an incentive for reuse and low compared to the value it is creating. The Water User Associations then distribute the water among their members/ farmers, while collecting an annual subscription fee, and also charging a mark-up on the water price to undertake routine repairs of the distribution network. The Ouardanine plant also supplies biosolids (sludge) on-demand as soil conditioner free of charge. ONAS recovers 40% of operation and management (O&M) costs from wastewater transfer to the irrigated plots (with the balance buffered by the CRDA), and has an overall operational cost recovery of 56% for the total wastewater treatment system when adding sewage taxes levied on households (FAO, 2014).

KEY PERFORMANCE INDICATORS (AS OF 2013)						
Land use:	65–75 ha under fruit trees					
Wastewater treated and reused:	Treated: 1,590m^3/day wastewater; 2050t/year sludge produced; of this reused: up to 410m^3/day wastewater; about 105t/year of treated sludge					
Capital investment:	USD 1.2 million for the treatment plant (1993) USD 337,000 for agroforestry system (1997)					
Labor :	About 46 farmers at the plantation; additional seasonal harvester					
O&M cost:	USD 30,500/year for treatment plant USD 11,700/year for wastewater transportation to the irrigated 65 ha					
Output:	USD 17,000/year from household sanitation fees (USD 5 per household and year) USD 1,950/year from CRDA selling water to GDA; sludge valued at USD 1,270 (data from Egypt) but uncounted as free USD 2,780/year from GDA selling water to farmers USD 817,000/year from fruit sales by farmers, not counting further gains along the value chain					
Potential social and /or environmental impact:	Water savings, public health and marine environment protection, nutritious food, carbon sequestration					
Financial viability indicators:	Payback period:	Depends on tree growth rate	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

In Tunisia about 84% of the generated wastewater is collected and treated at least 109 wastewater treatment plants. Nearly all (95%) of this water is treated at secondary level. A key motivation is the preservation of Tunisia's marine environment and coastal resorts, given the national importance of the tourist sector as part of Tunisia's overall commitment to prevent pollution in the Mediterranean Sea. As a semi-arid country, Tunisia is also aware of the pressure on its existing water resources and as many resources are saline, authorities are determined to increase water reuse.

In 2009, about 63 million m^3 (i.e. 26% of the annually treated 238 million m^3 wastewater) have been reused directly (agriculture, landscaping) or indirectly (aquifer recharge, etc.). The total agricultural area equipped for irrigation with treated wastewater was about 8,065 hectares (ONAS, 2009), although not all of this land might be actually irrigated. In addition, wastewater use has been reported for landscape irrigation such as golf courses (1,040 ha) and green areas (450 ha). The main crops irrigated across the country with treated wastewater are fruit trees (29%), fodder crops (45%), cereals (22%) and industrial crops (4%) (Bahri, 2002; Abid, 2010). In 2021, the plans are that 172 million m^3 would be made available for reuse on 40,500 ha farmland, 50 million m^3 for landscaping of 3,500 ha, and 25 million m^3 for aquifer recharge (ONAS, 2009).

Reuse has been regulated under the 1975 Code des Eaux (Water Code) and several more detailed decrees which are setting norms for chemical and biological loads in reclaimed water, prohibit the use of untreated effluents for irrigation and stipulated that reclaimed water could be used on a range of crops except vegetables or fruits that are consumed raw, such as tomatoes, lettuces, carrots and berries. The list of crops which could benefit from treated wastewater remains valid and includes industrial crops (e.g. cotton, tobacco, flax, jojoba and castor oil plant), grain crops (e.g. wheat, barley, oat), fodder crops (e.g. clover, corn, alfalfa), fruit trees (e.g. date palms, citrus trees, olive trees, vines), forest trees, flowers and herbs (e.g. rose, lily, jasmine, marjoram and rosemary).

The Ouardanine case is an example of a small and decentralized wastewater treatment plant which is serving about 3,400 households. Until 1993, the town of Ouardanine had to cope with the impacts of untreated sewage discharge. Environmental degradation combined with limited employment opportunities contributed to many local youth leaving this rural town. Called to remediate the untreated discharge situation, ONAS was met with pressing demands by local farmers to reclaim the water for irrigation. While ONAS implemented the treatment system, the CRDA elaborated the irrigation scheme with the farmers regrouped in a formal water user association, responsible for site selection, land rights resolutions and plant culture selection. This has allowed to ease use restrictions and avoid rejection of reclaimed water by users.

About 26 % of the secondary treated wastewater is reused by about 46 farmers for different fruit trees in an irrigation scheme set up in 1997 at a cost of USD 337,000, as part of the national water reuse program. Of the 65 (max 75) ha allocated for reuse, 34–45 ha were in recent years under peaches, 20–21 ha under olives and a small area under grapes, barley, alfalfa, cut roses and pomegranates. Drip and furrow irrigation are used. The wastewater treatment plant also produces sludge, but so far only a small percentage gets composted and recycled in agriculture in a free of charge pilot program. The application of biosolids on agricultural land is by law limited to experimental plots conducted as demonstration pilot projects.

Market environment

With some geographic variability, water scarcity is the defining feature of the agricultural economy in Tunisia. Against this backdrop Tunisia has since the mid-1960s increasing experience in wastewater reuse with a strong supporting legal framework and political commitment that has led to continuous expansion of wastewater treatment and reuse in the country. Perception studies show a reasonably high level of farmers' hypothetical acceptance to use reclaimed wastewater (80%), preferably without restrictions, and public acceptance (71%) to consume crops irrigated with treated wastewater (Abu-Madi et al., 2008). However, despite increasing water shortages and substantial economic incentives, actual demand for reclaimed water between 2001 and 2009 plateaued at around 25–30% of treated wastewater. According to Abu-Madi et al. (2008) and GWI (2010), factors that fuel the farmers' hesitation are: (i) availability of or accessibility to freshwater; (ii) distrusted water quality; and (iii) worries about crop/fruit marketing and acceptance. Less important are however concern for public criticism, concern for health impacts, religious prohibition, or psychological aversion. Reasons for water quality concerns which led farmers to fall back on conventional resources include (GWI, 2010):

- Plant saturation (particularly in coastal areas and in summer when tourist numbers put a strain on capacities) and ageing.
- Industrial pollution due to poor upstream pre-treatment (a legal requirement for industrials but often poorly observed in practice) which refers in particular to salinity in central and southern Tunisia.

The existing system for crop marketing in which crops produced with reclaimed-water crops are on offer together with freshwater irrigated crops 'facilitates' marketing although some consumers seem to be able to distinguish between the crops. However, there are calls for more transparency and monitoring, also to increase the confidence of the consumer. So far only the national market is targeted. According to Abu-Mari et al. (2008) Tunisia has not yet reached a stage where the crops irrigated with reclaimed wastewater can be exported.

Sludge reuse has been tested on pilot farms (about 300 ha) for several years, in line with the national standards (Normes Tunisiennes (NT) 106.20 – 2002) (MAERH, 2003; ONAS, 2009). Also at Ouardanine soils were amended under the regular monitoring of the Ministry of Agriculture as one of the demonstration projects. The estimated amount of 6 t sludge/ha is expected to be spread over five years.

Macro-economic environment

All of Tunisia's infrastructure has been financed by the state, usually with a combination of loans and grants from state finance and international lenders. Tunisia has good links, e.g. with the European Investment Bank, the Agence Française de Dévloppement, the German KfW, the Japan International Cooperation Agency, etc. Most new wastewater treatment plants are medium-sized plants (15,000m^3/day), built on a turnkey contract basis and financed by ONAS with international loans. But also different financing and procurement avenues are being explored, including a 25-year BOT contract for the construction of two large WWTPs.

Tunisia is determined to reduce the discharge of the wastewater to the sea, and to develop water reuse. The government policy strongly supports wastewater treatment and incentivizes wastewater reuse. Sanitation charges for domestic users, industry and tourist establishments vary according to water consumption and the principle of 'polluter pays' and do so far only cover about 60–65% of ONAS's operational costs, which comprise personnel salaries (about 30%), energy (60%) and equipment repairs and replacements (10%). The rest is financed by the state.

Cost recovery via wastewater use is constrained by water pricing. The tariff set by the Government in 1997 demanded Tunisian dinar (TND) 0.02/m^3 (ca. USD 0.02/m^3 at that time, or USD 0.015/m^3 in 2010). The target is to keep the price for reclaimed water significantly below the one of the subsidized freshwater[1] which was about 3 to 4 times higher for irrigation, and 7–40 times higher for domestic and industrial use in the year 2000 (Bazza and Ahmad, 2002; GWI, 2010). The price for reclaimed water has remained unchanged since 1997 and covers only a fraction of the real cost of wastewater treatment, estimated at TND0.3–0.7/m^3 (GWI, 2010).

Despite the low price charged to Tunisian farmers for reclaimed water compared to conventional water supply, the demand for reclaimed water remained so far modest (Qadir et al., 2010). The mismatch has (i) in part geographical reasons with most wastewater being produced in the Greater Tunis area and along the coast, i.e. not where it is mostly needed; (ii) is supported by the availability of alternative water sources like shallow groundwater which only attracts pumping costs until a depth of 50m (FAO, 2009); and (iii) is also driven by seasonal demand–supply gaps.

Business model

The treated wastewater coming for free from the wastewater treatment plant of Ouardanine is pumped to a ground reservoir which is under the supervision of the Regional Offices of Agriculture Development (Commissariat Régional de Développement Agricole, CRDA). The CRDA also operates the pumps and wastewater distribution network connecting to the irrigation scheme. CRDA sells the water in bulk to the Water User Associations (Groupement de Développement Agricole, GDA), at a price of TND 0.02/m^3 (2013: USD 0.012/m^3) which recovers about 17% of the costs of CRDA to convey the water to the irrigation scheme; the balance is covered by the Ministry of Agriculture.

The GDA then sells the water to the farmers at TND 0.035/m^3 (USD 0.022/m^3), thus earning a mark-up of about USD 0.01/m^3. Besides wastewater sales to the farmers, the GDA also raises revenue (about USD 1,250) from the annual subscription fees paid by farmer (USD 32 per farmer) which allows them to support CRDA with minor maintenance of the irrigation network at farmers' end. According to FAO (2014) farmers are the main beneficiary of the irrigation system with an annual income from their production sale of about USD 5/m^3 or USD 12,570/ha. Moreover farmers engaging in reuse are entitled to purchase irrigation equipment at a 30% discount, or use for free treated sludge (Figure 211).

FIGURE 211. BUSINESS MODEL CANVAS OF ONAS SUPPORTED WATER REUSE FOR GROWING FRUIT TREES IN OUARDANINE, TUNISIA

KEY PARTNERS

- Regional Offices of the Agriculture Department (CRDA)
- Water User Associations (GDA)
- Fruit market and consumers (public acceptance)
- Sewer connected households
- ANPE and DHMPE as monitoring agents

KEY ACTIVITIES

- Collection and treatment of wastewater
- Sludge drying and composting
- Maintenance of irrigation supply network (via CRDA)
- Collection of water fees and charges

KEY RESOURCES

- Treatment plant and treated wastewater
- In and outflow network
- Interested farmers in vicinity
- Land (or machinery) for sludge drying and composting

VALUE PROPOSITIONS

- To transform wastewater and sludge into safe products for reuse in peach and olive orchards

CUSTOMER RELATIONSHIPS

- Government to government contract (ONAS/CRDA)
- Automated system for tariff payment (ONAS/Households)
- Government to private sector contract (via CRDA to GDA)

CHANNELS

- Roundtable (water reuse)
- Online payment (house-hold sanitation fees)

CUSTOMER SEGMENTS

- Regional Offices of the Agriculture Department (CRDA)
- Water user association (GDA) and its farmers
- Private sector (golf resorts)

COST STRUCTURE

- Treatment plant, capital cost and operational costs including in-house monitoring of water and sludge quality
- Water conveyance to CRDA reservoir (or water user association)
- Opportunity costs of idle reuse capacity
- Customer service and fee collection

REVENUE STREAMS

- Household wastewater fees (via water bill)
- Bulk sale of wastewater (and potentially sludge)
- Governmental subsidy; carbon credits (potential)

SOCIAL & ENVIRONMENTAL COSTS

- Possible long-term risk for groundwater and food safety
- Occupational risks
- Monitoring failure can lead to loss of trust with high costs across all reuse schemes

SOCIAL & ENVIRONMENTAL BENEFITS

- Year-round water reuse resulting in less discharge into water bodies
- Nutritious fruits from wastewater irrigation
- Orchard amenity value and ecosystem functions
- Less human exposure to untreated waste
- Created a new resource and employment

Available data compiled by FAO (2014) indicate that the treatment system in Ouardanine is recovering about half of its operational costs from household fees, while the CRDA as intermediary recovers about 17% via the internal contribution of the water user associations. Other sources mention 25%. Governmental subsidies remain crucial for the remaining pumping and maintenance work. The Water User Associations (GDA) itself is in a better position to charge its members enough to break even, whereas the individual farmers make profit.

Value chain and position

There are four main 'business' segments in the value chain. These include the wastewater treatment plant; bulk sale of treated wastewater by the local agricultural authorities to the water user association; and distribution and resale of wastewater to its members. The resource recovery cycle gets closed with the irrigated fruits entering the market. Each segment also has responsibilities for the operational aspects of the transformation from wastewater to fruit. The key business activities for the wastewater treatment plant are the treatment of wastewater to obtain its environmental sustainability objectives. A secondary objective is recovering costs. The involvement of intermediaries between ONAS and farmers makes much sense as the treatment plant has neither capacity nor expertise in dealing with farmers. Water sale to farmers generates revenue for CRDA and the water user association. CRDA is in charge of water transfer (2.5 km pipeline), pumps and routine maintenance work. Farmer and traders up the value chain make net profits (Figure 212). The business activity also involves production and treatment of sludge for composting and fertilizer yet generates no revenue but saves disposal costs.

The value chain and market position could be elevated through better collection and rationalization of sewage taxes, water pricing to achieve full cost recovery, sludge sale to outside buyers (potential) and channelling a larger part of farmer revenues to investment in the maintenance of the pumps and water transport. Additional revenue from forest carbon sequestration would depend on the size of the plantation and could be explored. With households being the source of the water and recipient of the fruits, it is obvious that an important component is the compliance with health standards, i.e. the monitoring responsibilities of the involved actors.

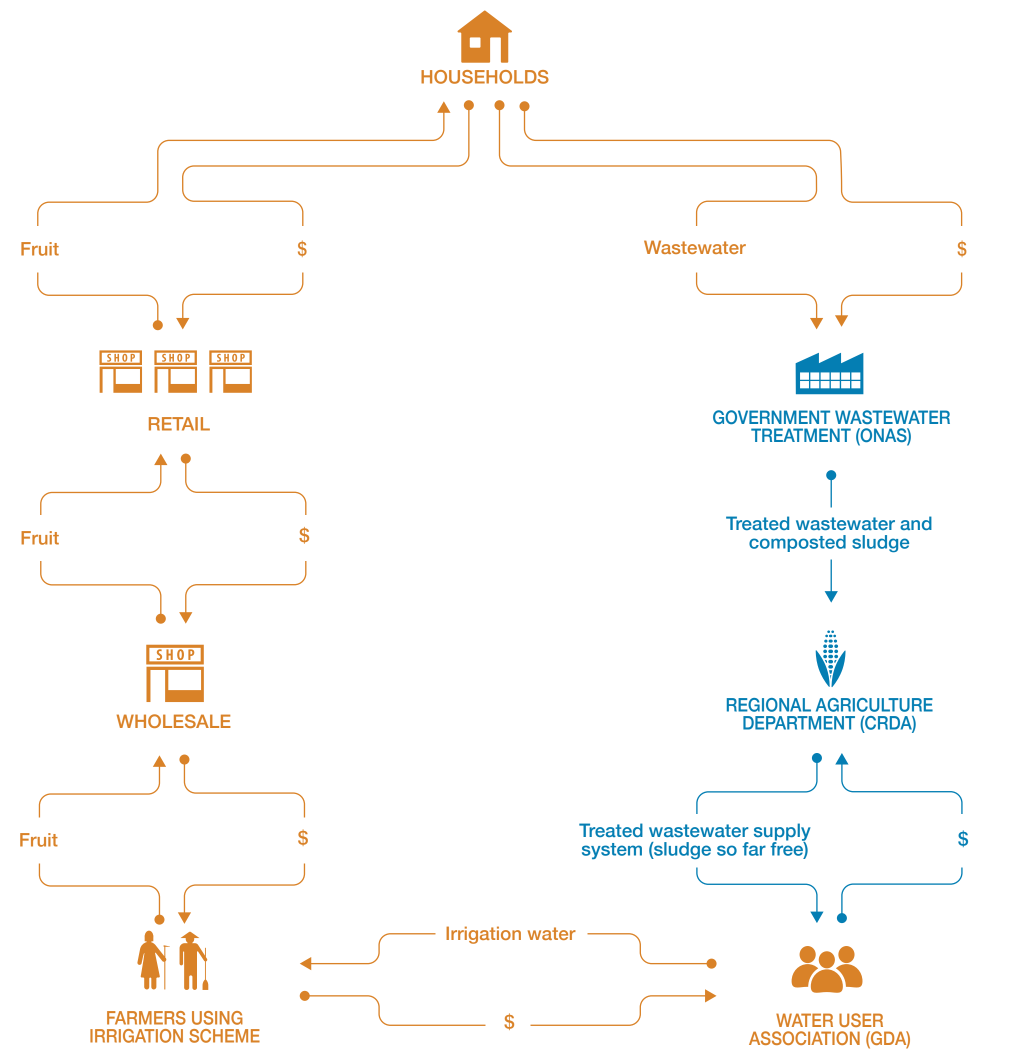
Institutional environment

Under the Ministry of Environment and Sustainable Development, ONAS is the central authority charged with protecting water resources and for this with managing the wastewater systems from collection to treatment and disposal. ONAS is in charge of sanitation planning to operation and maintenance throughout Tunisia. However, the monitoring of wastewater treatment plants, i.e. treatment standards and discharge quality, is with the National Environmental Protection Agency (ANPE) and the Department of Hygiene and Environmental Protection (DHMPE). Several other ministries (see Box 7) are also involved in wastewater reuse. The private sector plays a role where wastewater is reused, e.g. for golf courses, which for their part, own and operate their infrastructure ensuring the transfer of treated effluents from the treatment plant to the field.[2] All investment and operational costs must be met by the golf course operators, but they do not pay for the water provided by ONAS.

From a scale perspective, water used for irrigation is managed at three levels: at the national level are the Ministry of Environment and Sustainable Development and its sanitation utility ONAS; at the regional level the 24 Regional Offices of Agriculture Development (CRDA); and at the local level the Water User Associations (GDA) whose objective is to ensure self-management of the hydraulic systems established by the state for irrigation.

Operation and maintenance costs are covered by the governmental budget as well as by the farmers. CRDA, under the supervision of Ministry of Agriculture, Hydraulic Resources and Fisheries, is the main

FIGURE 212. BUSINESS PROCESS FLOW OF THE OUARDANINE TREE CROP SYSTEM



responsible entities for operation and maintenance of the wastewater distribution network. The GDA are essentially associations of farmers that take responsibility for minor maintenance of the irrigation systems, as well as selling water, collecting water fees and keeping accounts. The GDA also sets fees and users' contributions to cover all the costs of running the association. This kind of regulatory structure and the devolution of management responsibility for wastewater treatment and supply to the user level has enabled significant improvements in terms of a participatory reuse planning and management.

Considering the strong Governmental support of both public entities, ONAS and CRDA in this context and the lack of financial transaction between both, it might be justifiable to say that both entities co-convene the business model.

Box 7. Main government bodies and institutions for wastewater treatment and reuse in agriculture in Tunisia (updated from GWI 2012)

Ministry of Agriculture, Water Resources and Fisheries: formulates regulations on water resources, including irrigation and water reuse in agriculture.

Regional Offices of Agriculture Development (CRDA): under Ministry of Agriculture, and responsible for the distribution of treated wastewater from the plants to irrigated perimeters through pumping stations and a supply network while coordinating the monitoring of water quality.

Ministry of Public Health: sets standards for drinking water and effluent discharge to the environment with the focus on human health protection.

Department of Hygiene and Environmental Protection (DHMPE): a division of the Ministry of Health which controls the sewage system and purification stations as well as irrigation water to ensure compliance with public health standards.

Ministry of the Environment and Sustainable Development: formulates regulation for environmental protection and the prevention of pollution, including effluent discharge standards and reuse standards.

National Environmental Protection Agency (ANPE): in charge of preventing and controlling pollution and sole body controlling direct discharge of effluents from an environmental health perspective, including monitoring of ONAS's treatment plants. Like ONAS, ANPE works under the Ministry of the Environment and Sustainable Development.

National Sanitation Utility (ONAS): responsible for the country's wastewater infrastructure. It collects, treats and discharges municipal (and some industrial) effluents and sells (heavily subsidised) treated wastewater for reuse.

National Water Supply and Distribution Company (SONEDE): Tunisia's bulk water supplier and main drinking water utility, which serves all urban areas and about half the country's rural areas.

Ministry of Tourism and Handicrafts: supervision of societies in charge of golf courses including irrigation.

Wastewater reuse is covered under Tunisia's Water Code from 1975, which is the overarching legislation covering the water sector. Different supporting decrees define norms for chemical and biological loads in reclaimed water (based on FAO and WHO recommendations), those crops that could benefit from reclaimed water and the terms and conditions and precautions required for using reclaimed water in agriculture (such as cattle not grazing on land that has been irrigated with reclaimed water, or sprinklers not being used for the irrigation of fruit trees). Excluded from reuse are vegetables or fruits that are consumed raw. However, as exactly vegetables are a key cash crop, there is a strong call for high quality treatment to include also vegetables. As there is also a call to extend aquifer recharge with treated wastewater, Tunisia started recently revising its reuse norms to reflect quality norms for different applications (irrigation, landscaping, aquifer recharge, industrial use, etc.).

While effluent quality is monitored by ONAS and ANPE, an explicit risk management system is missing and enforcement of corrective measures remains limited given that one Governmental body is monitoring another, in part under the same ministry (ANPE and ONAS). Theoretically, if treated effluents fail to comply with the standard NT106.03, CRDA has to notify ONAS to turn down the treated effluents. If other water supplies are scarce (notably in summer) it is not unusual for CRDAs to accept below par treated effluents. On the other hand, it is interesting to note that sector performance seems to be motivated by the 'carrot' rather than the 'stick': the impact that poor water quality, environmental pollution and scarce water resources have on the economy and society seem to be enough to keep the sector on its toes (GWI 2012).

Sludge reuse as a fertilizer for agricultural purposes is permitted as long as it derives from urban wastewater treatment plants, i.e. not from pre-treatment by commercial and industrial facilities to remove harmful pollutants, or is recovered from cleaning of wastewater infrastructure. Sludge cannot be applied to land used for the cultivation of vegetables (GWI 2012).

Technology and processes

Reclaimed water receives in 95% of all cases secondary treatment in Tunisia, mostly via activated sludge systems. Tertiary treatment is seldom (5%) and was so far only considered in exceptional circumstances for specific uses because of its cost. Treatment technologies comprise low (56%) and medium load (30%) activated sludge plants, stabilization ponds (lagoons 14%) and in a few cases trickling filter and others systems making treated wastewater sufficiently safe for reuse as permitted in the Water Code. In general, ONAS's compliance with environmental discharge standards is with 80–90% high (GWI, 2012; Table 48).

In Ouardanine, the treatment process consists of preliminary, primary and secondary treatment (activated sludge process). The Ouardanine wastewater treatment plant supplies secondary treated wastewater to the Ouardanine peach, olive and pomegranates orchards. The plant receives raw wastewater from 3,400 households (around 17,000 citizens) and the daily treatment capacity is around 1,000 to 1,590m^3. The collected wastewater is to 91% of rural and domestic origin (residential, commercial and institutional), to 9% of industrial sources. The following Table 48 reports some key indicators of raw and reclaimed water discharged from the Ouardanine wastewater treatment plant compared to the agricultural reuse standard.

After primary treatment, the secondary step consists of an aeration tank with activated sludge in which the organic content of the sewage is digested by microorganisms. The remaining wastewater is subsequently pumped to a final clarifier which allows the sludge to settle. Parts of the secondary

TABLE 48. AVERAGE ELEMENT CONCENTRATION FOR TREATMENT PLANT INFLOW AND OUTFLOW

PARAMETER	BEFORE TREATMENT	AFTER TREATMENT	TUNISIAN STANDARD*
pH	7	8	6.5 – 8.5
Total Suspended Solids (TSS)	386	28	30 mg/L
Chemical Oxygen Demand (COD)	1,131	80	90 mg/L
Biological Oxygen Demand (BOD)	472	31	30 mg/L
Chloride	622	426	2,000 mg/L

* Tunisian Standards NT 106.03, 1989

Source: Salem et al., 2011

sludge is (usually mechanically) dried and composted to be used as a soil conditioner at rates of 6–11t/ha/year.

The irrigation scheme of Ouardanine was set in 1997 as a part of the national water reuse program and covers 65–75 ha of irrigated land and orchards cultivated by about 40–46 independent farmers. The CRDA operates the wastewater distribution network and is responsible for the organization of water quality monitoring. About 70% of the total irrigated area are cultivated with peaches and the remaining area with olives, grapes and pomegranates. A young peach tree begins fruiting by the third year after planting, which keeps the investment period much lower than for wood plantations (e.g. Egypt). Mature crop yields can reach up to 35t/ha for peaches and 7t/ha for olives.

The treated wastewater coming from the wastewater treatment plant is pumped during 20 hours/day to feed a ground reservoir with a capacity of 1,000m^3. According to Decree No 89–1047, CRDAs must test the quality of the treated effluents before using them, with regular controls from ANPE and DHMPE. The water must be tested for bacteriological load fortnightly. Tests for the water's pH, BOD, COD, TSS, chloride, sodium, ammonia, nitrogen and electrical conductivity must be carried out at least monthly. And tests for a broad range of heavy metals and other potential contaminants must be carried out at least once every six months (GWI, 2012). From the reservoir the water is then pumped to the distribution system of the orchard passing a battery of sand and gravel filters. The pumping station is not supplied with potable water. The total amount of treated wastewater used to irrigate the field is estimated at 2,300m^3/ha/year. Drip irrigation is the most frequent irrigation systems adopted in Ouardanine: about 60% of the field is irrigated by drip irrigation and the rest is irrigated using furrow irrigation. As the water still contains pathogens (Salem et al., 2011), irrigation remains restricted to certain crops. Some slight restrictions also derive from water salinity, which is moderate.

Funding and financial outlook

The funding and financial outlook for the Ouardanine wastewater treatment plant and agroforestry systems is positive due to clearly defined institutional responsibilities and opportunities for cost recovery within a regulatory framework which supports commercial reuse. Although public sector subsidies are well justified given the strong policy support and environmental and economic benefits (tourist sector) of wastewater treatment and reuse, charging for wastewater is an important step towards cost recovery. While cost recovery for water treatment and transport is still sub-optimal, there are options for improvement.

A higher cost recovery rate will be possible, e.g. via the sewage tax paid by the households, which could reflect more on the treatment costs rather than just the connecting fees. Wastewater charges paid by the farmers could also be adjusted to further support cost recovery for water conveyance. This could be at the end of the CRDA if it is allowed to revise the 1997 fixed rate of TND0.02/m^3 or at the end of the water user associations. A preliminary analysis based on the data reported in FAO (2014) shows significant scope for improving cost recovery. In general, it would be useful to learn from irrigation systems with higher than average cost recovery rate. Between different reuse schemes cost recovery can vary in wide margins (e.g. 13–63%) (Chenini et al., 2003). A third important step is to cut costs. ONAS has launched a comprehensive programme to rehabilitate and extend 19 of its treatment plants (including Ouardanine) in a bid to improve their compliance with standard NT106.02. Aside increasing the plants' capacity, ONAS plans to retrofit the plants with fine bubble aeration systems and/or biogas co–generation facilities to cut back on energy costs while improving water quality. A fourth opportunity is to start selling the treated and composted sludge to farmers and for landscaping.

The willingness to pay for treated wastewater is mostly undermined by the ability of many farmers to fall back on groundwater use, which is free of charge if found above a depth of 50m (FAO, 2009). However, extraction is increasingly unsustainable and there are options to regulate this, e.g. via pumping (electricity) charges. On the other hand, farmers' willingness to pay is increasing if water quality could allow growing vegetables which are the most appreciated cash crop (Abu-Madi et al., 2008).

Socio-economic, health and environmental impact

The Ouardanine project has eliminated raw wastewater discharges to the environment/ocean, while sustaining a strong new economic activity for a local farmer association. This is an example how investments in comprehensive wastewater collection, treatment and reuse can lead to positive impacts, locally and beyond, as marine pollution gets reduced which positively affect the overall economy given the importance of the tourist sector. About 70% of all treatment plants are located in towns and cities along the urban coast. Other positive impacts in the Ouardanine case relate to savings of freshwater, including the stressed groundwater reserves, local employment and support of economic activities and gains along the fruit value chain.

The trust in reclaimed water in Tunisia is based on comprehensive research on the possible impact of irrigation on crops, soils, groundwater and human health, which showed that in general the concentrations of almost all regulated elements in reclaimed water are below the maximum concentration recommended for agricultural reuse by the Tunisian standards (Bahri, 2002; Berglund and Claesson, 2010). However, different treatment processes show different results, with stabilization ponds performing best for microbial indicators, offering opportunities for unrestricted irrigation. Other treatment systems only support restricted irrigation unless other options (e.g. the multi-barrier approach) for pathogen reduction are put in place as promoted by WHO (2006) and IWMI (Amoah et al., 2011). Where crop choice is restricted, like in the example of citrus fruits, care has to be taken that the fruits are not in contact with the soil. To minimize risks, a non-irrigation period of 10–14 days is used in Ouardanine before crop harvest to support natural die-off (Berglund and Claesson, 2010), which is however not always easy as some fruits need regular watering. Occupational risk mitigation options and fencing against third parties will be routine measures to control related impacts. ONAS embarks also on a program to mitigate bad odor (via filtering, spraying, treatment plant coverage) and treats possible mosquito breeding grounds within its treatment premises and canals (MAERH, 2003).

Application of reclaimed water on different soils showed little modifications of their physical and chemical properties, except for a normal increase of salinity as also observed under irrigation with freshwater. However, there are regional differences in salinity level (see above) which can also be influenced by the treatment process making treated water less preferred than groundwater. Aside from salinity, also nutrient supply can be higher in reclaimed water resulting in better annual and perennial crop yields, but might also affect the balance of vegetative growth vs. fruit development. Therefore, irrigation with reclaimed water (and also sludge application) has to be considered as a complementary fertilization that has to be taken into account when calculating fertilizer application rates (Bahri, 2002; Mahjoub, 2016).

Scalability and replicability considerations

Tunisia is setting an exceptional example with higher investments in sanitation than drinking water, which is normally the opposite in the region. It is thus no surprise that it is the most advanced country in North Africa with regards to water and wastewater infrastructure, including regulation. The Ouardanine case, also small in scale, is in this context an excellent example of a decentralized treatment for reuse scheme. Key drivers for the success of the business are:

- A clear regulatory framework permitting reuse for a wide variety of seasonal and perennial crops against the payment of a water fee.
- Governmental will, financial support and inter-institutional cooperation down to water user associations.
- Early participation of the users.

In view of a more or less stagnant reuse rate, Tunisia's plans to multiply the volume of reclaimed water it uses in the years to come, targeting a 60% reuse rate, appears very ambitious, but not totally unrealistic since Tunisia is addressing head-on some of the main challenges that have delayed the development of the reuse sector until now – geographic imbalance, water tariffs, treatment quality and related reuse standards: (i) The geographic challenge is that most water needs are inland while most wastewater generation and easy disposal is along the coast. A major project for 2016–2021 is the planned transfer of treated wastewater from Tunis to the country's arid interior which will include irrigation of 25,000 ha as well as aquifer recharge of 30 million m^3 (World Bank, 2011). This builds on recharge experiments which started already in 1992. (ii) Compared to Egypt, where in the aftermath of the Arab spring authorities are thinking twice about any changes of tariffs, Tunisia used the wind of change to address chronic deficits in its national utilities by raising tariffs. The benefits of a rational increase of freshwater tariffs are threefold: first, it would make reclaimed wastewater more attractive. Second, it may help in saving water. Third, it could be used to recover part of the costs of conveyance and distribution of reclaimed wastewater. (iii) The quality challenge ONAS tries to address through the rehabilitation and extension of its treatment plants. ONAS has identified 48 plants (including Ouardanine) that it wants to equip with tertiary treatment facilities. The plants are located in areas with significant irrigation needs and the programme's objective is to produce 150 million m^3 of effluents treated at tertiary level (GWI, 2012) which would support unrestricted irrigation if the newly revised (but not yet published) reuse standards provide space for this option. For about 96% of the surveyed farmers by Abu-Madi et al. (2008) improving the quality of treated wastewater and allowing unrestricted irrigation have the power to change the negative attitudes of farmers with respect to reuse.

However, these measures might not be sufficient and attention will also be required to address other reasons for low reuse demand. Farmers complain for example about a mismatch in seasonal supply and demand which requires more investments in inter-seasonal storage facilities. Another key challenge is that compared to, for example, Jordan or Israel, many irrigators in Tunisia have more choices about which type of water to use than wastewater. In distinct contrast to, e.g. Israel and Jordan, reclaimed wastewater in Tunisia has not been mixed into reservoirs or aquifers or is by law replacing freshwater, thus many farmers can simply avoid using it, and opt for shallow groundwater which only costs pumping (FAO, 2009; Kfouri et al., 2009). To allow reuse to boom, the use of alternative water sources has to be restricted, like through higher electricity or diesel charges for pumping or aquifer protection by delineating perimeters where the quantity and quality of groundwater is compromised. Shallow groundwater accounts for 40% of groundwater use. This is now used almost exclusively for agriculture and it is being over-exploited nationally as demand exceeds supply. Faced with this situation, the government already decreed that a number of aquifers would be protected and drilling would be subjected to prior approval. The government also subsidizes water saving techniques up to 60% of the investment costs in irrigation systems when switching from traditional furrow irrigation to more water-saving methods like sprinklers or drip irrigation (Mahjoub, 2016).

Summary assessment – SWOT analysis

The strength of this business case is in its inter-departmental institutional setup with representation from the sanitation sector, environmental protection, health, agriculture and water users, a clear regulatory framework, charges for reclaimed water and promising options for increasing cost recovery

aside a strong governmental will to support treatment and reuse. The regulatory framework is offering a variety of crop options although it could be extended in line with WHO (2006). Figure 213 presents the SWOT analysis of the Ouardanine case within its larger context.

FIGURE 213. SWOT ANALYSIS FOR OUARDANINE WASTEWATER AND AGROFORESTRY SYSTEM

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Sound institutional arrangements across agriculture–sanitation sectors ▪ Multiple choices of crops and high economic benefits to farmers ▪ Early farmer participation and sale of treated wastewater at reduced price ▪ Reasonable O&M cost recovery with options for improvement ▪ Continuous availability of wastewater, especially if inter-seasonal storage is supported ▪ Investments in cutting energy costs ▪ High compliance with safety standards	**WEAKNESSES** ▪ Use of reclaimed water remains under potential ▪ Tertiary treatment needed to support water acceptance and unrestricted reuse ▪ Sludge use undervalued ▪ No legal provision for risk management to allow unrestricted irrigation of vegetables ▪ Monitoring of heavy metals should not be underestimated
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Political commitment with increasing private sector support ▪ Current revision of reuse standards, planned investments in tertiary treatment, and transfer of reclaimed water to high demand areas ▪ Willingness to increase freshwater tariffs to make reclaimed water more attractive ▪ Opportunity to sell treated sludge ▪ Cost recovery for reclaimed water supply would increase by restricting groundwater access	**THREATS** ▪ Mismatch between governmental push for reuse and public perception of reuse ▪ Monitoring failure can lead to loss of trust with high costs beyond this reuse scheme ▪ Availability of alternative water sources with less risk (seasonal variation in quantity and quality, public perception)

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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014/16. As business operations are dynamic data can be subject to change.

Notes

1 In 2007 average public irrigation costs with freshwater were USD 0.097/m^3 and the average tariff applied was USD 0.084/m^3 – a national average cost recovery rate of 87%. Total cost recovery, however, based on infrastructure and operating cost remains low at 25% (FAO, 2009).

2 As at end of June 2009, the private sector operated 2,206 km of sewers and 17 wastewater treatment plants. It is also worth mentioning that the new regulations stipulate the adoption of concession contracts that can extend the contracts up to 30 years (ONAS, 2009).

CASE

Suburban wastewater treatment designed for reuse and replication (Morocco)

George K. Danso, Munir A. Hanjra and Pay Drechsel

Supporting case for Business Model 17	
Location:	Drarga, suburban Agadir; Morocco
Waste input type:	Domestic wastewater from Drarga town
Value offer:	Tertiary treated wastewater for irrigation, with capacity to produce organic fertilizer, reed grass and energy
Organization type:	Public
Status of organization:	Plant operations started in 2000; the reuse operation inaugurated in 2001
Scale of businesses:	Small with up to 1,800 to 2,700m^3/day (design capacity 600–1,000m^3/day) and 6–16 irrigated ha
Major partners:	National electricity and water company (ONEE); Ministry of Energy, Mining, Water and Environment, Drarga town and Prefecture of Agadir, Al Amal water users association, local farmers

Executive summary

The wastewater treatment plant in the town of Drarga (ca. 17,000 inhabitants in 2004) has attracted international attention as an example of (i) an applied low-cost technology designed and managed in close consultation with local stakeholders; (ii) a system able to support local resource recovery demands for revenue generation; (iii) a system with marketing plan for replication across towns and suburbs; and with (iv) a dedicated accounting system to support full financial cost recovery. The treatment technology involves screening, anaerobic basins, denitrification, a water recirculating sand filter system and reed beds. The effluent meets the World Health Organization standards for unrestricted use in irrigation. The RRR options the plant offers are internal energy recovery, and the possible sale of tertiary treated water, reed, and sludge based co-compost. Although the demand for resource recovery remained optional, the Drarga plant achieved its objective of operational cost recovery while eliminating soil and aquifer pollution from raw sewage. Controlled trials verified that farmers using the water could save significantly on pumping and fertilizer costs while gaining higher yields and profits. However, in 2004, the plant's operations were centralized under ONEP (now ONEE)[1] which deemphasized the exploration of resource recovery and reuse as revenue streams. This might change again as the use of treated wastewater is strongly supported in Morocco due to scarcity of water resources and recurring droughts.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land use:	Plant: 2 ha; up to 16 ha irrigated (under potential)					
Water treated:	1,800 to 2,700m^3 per day (design capacity 600–1,000m^3 per day)					
Capital investment:	Total investment USD 1.7 million					
Labor:	About 5; ca. 27% of the O&M costs					
O&M cost:	USD 2,300 to 3,600 per month					
Output:	Tertiary treated wastewater					
Potential social and/or environmental impact:	As there was no treatment before, inhabitants in Drarga gained most of all from health risks reduction and an improved living environment					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Morocco is facing severe water shortage with less than 800m^3 water per capita. Frequent and recurring droughts, rising demand for water,and pollution of freshwater threaten water security in Morocco, also affecting the tourist sector like in the Agadir region where Drarga is located. The Drarga treatment plant was constructed as one component of the Morocco Water Resources Sustainability (WRS) project (1996–2003) co-funded by the Moroccan Government (Ministry of Environment[2]) and the United States Agency for International Development (USAID). The area around Drarga is semi-arid with annually 236mm of rain in the winter months. Agriculture around the town depends on the limited water resources from the Souss-Massa River Basin (SRB). The Souss river is most of the year dry, and the aquifers in the region which are already to 95% supporting agriculture cannot cope with further withdrawal, making treated wastewater a promising alternative.

Today, many Moroccan towns have sewer systems, and the number of (functional) treatment facilities is on the increase. Also in Drarga, about 80% of local households are connected to a sewage system. However, before the treatment plant was constructed, Drarga's raw sewage was discharged through four outfalls into the environment, contaminating the aquifer and creating unhealthy sanitary conditions. This uncontrolled release of wastewater into the environment is still a common situation in many smaller and larger towns in and outside Morocco.

The Drarga treatment plant was inspired by a similar technological setup piloted in the 10-km distant Ben Sargeo and designed in consultation and partnership with the local community in Drarga and institutional stakeholders across administrative scales using a participatory approach. The feasibility study analyzed various options for selection of the site and of the technology for the plant, a detailed financial and economic analysis based on different water reuse scenarios, following an assessment of the community's willingness to accept crops irrigated with treated wastewater (EAU, 2004).

Market environment

For the Drarga wastewater treatment plant's O&M costs to break even, it is essential to combine low operational costs and sufficiently high revenue streams. Aside the sewage fee paid by households, the sale of treated wastewater to farmers is one of the most prominent design revenue streams. A wastewater tariff of USD 0.05/m^3 was suggested which is half the fresh water price. However, although the initial feasibility studies confirmed consumers' acceptance of the concept, the study fell short to predict farmers' refusal to pay for the treated water, arguing that the water will anyway be released after treatment (Dadi, 2010). Given the sufficiently high revenues through the water bill (see "Funding and financial outlook" below), the market for compost or reed was not explored by the operators.

Finding an acceptable and competitive price for wastewater compared to the freshwater tariff and aquifer pumping is a common challenge across the MENA region. In some regions where the level of the groundwater has witnessed a considerable decrease, like around Agadir, the pumping costs have however become very expensive (up to USD 0.14/m^3) which is increasing the financial competitiveness of the treated wastewater, but not improve its stigma, even with tertiary treatment as other farmers reported who were concerned about their image in view of crop exports (Dadi, 2010; Salama et al., 2014).

Macro-economic environment

Although Morocco is a water-scarce country, 46% of the active population works in the agricultural sector (80% in rural areas) contributing 14% of the gross domestic product (GDP). The agricultural sector's exposure to water stress and climate variability causes fluctuations in its economic contribution: its share of GDP ranges from 11% in water-scarce years to over 20% in years when the climate is favorable (Houdret, 2012). Recent estimates indicate an average water availability of around 730m^3 per person per year, which is significantly lower than the often cited 1,000m benchmark[3], and might further decline to 580m^3 by 2020, which poses a significant challenge to the government. In addition, the quality of water resources is deteriorating at an alarming rate as only 25% of the collected wastewater is actually treated (Hirich and Choukr-Allah, 2013). In an attempt to rectify these problems, the Government of Morocco is heavily investing in new treatment plants and recommends to make use of non-conventional water sources such as treated wastewater for extending irrigated areas, exploiting arid lands, improving public health, controlling environment pollution and managing the quality of water resources at the level of hydrographic basins (Salama et al., 2014). The *Liquid Sanitation and National Wastewater Treatment Programme* (2005), the *Green Morocco Plan* (2008) and the *National Water Strategy* (2010) support the agricultural reuse of treated wastewater (Salama et al., 2014). As of 2011, only 13% of the 32.38 million cubic meters (MCM) of treated wastewater was reused in agriculture across the country, a share which is expected to reach 50% by 2020 (MEMEE, 2013)[4]. The Drarga plant offers in this context the double value proposition of safe treatment and water for reuse at a favorable benefit–cost ratio which is tailored to smaller towns and suburbs targeting agricultural water reuse.

Business model

This is a cost-recovery business model which combines low investment and running costs with multiple cost recovery options supported by a special account to manage costs and revenues of the plant. Aside the use of household fees for the sewer connection, the plant can generate parts of its energy needs and obtain revenues from selling reed grass, highly treated wastewater and organic fertilizer to farmers, depending on demand; see Figure 214 on the following page.

Value chain and position

The plant treats wastewater from the Drarga commune against a fee (charge with the water bill) and sells depending on demand tertiary treated water to farmers which is of increasing interest where groundwater availability and pumping costs become challenges. Farmers benefit through guaranteed all-year access to low-priced water, and savings on fertilizer. A number of local field trials showed that farmers can gain through the use of the treated wastewater between USD 80 and more than USD 500 per ha with variations between crops (EAU, 2004; Choukr-Allah et al., 2005; Choukr-Allah and Hamdy, 2005; Mohamed and Young, 2013). Common crops in the areas, irrigated via surface, micro jet or drip systems are for example wheat, maize, tomatoes, zucchini, alfalfa and clover. With on average doubled yields using wastewater compared to irrigation with other water sources (Hirich and Choukr-Allah, 2013), price advantages could also be extended to consumers (Figure 215).

The volumes of actually realized water reuse and irrigated hectares vary between sources. The volume of treated effluent increased from 170m^3 per day (in the year 2000) to 400m^3 in 2010, irrigating initially

FIGURE 214. BUSINESS MODEL CANVAS – DRARGA DESIGN FOR REUSE

KEY PARTNERS

- Former 'Water Resources Sustainability (WRS) project'
- Ministry of Environment
- Al Amal Water User Association
- ONEP (initially as partner, later as operator and owner)
- Town and provincial authorities

KEY ACTIVITIES

- Wastewater collection and treatment
- Provision of treated water to potential users
- Possible supply of reed grass and organic fertilizer

KEY RESOURCES

- Treatment plant (capital investment), wastewater
- Dedicated bank account
- Partnership across scales
- Expertise (ONEP)

VALUE PROPOSITIONS

- Operational cost recovery, enhanced public and environmental health, combined with optional water, nutrient, biomass and energy recovery and reuse

CUSTOMER RELATIONSHIPS

- Indirect to farmers via water user association
- Computer based household billing
- Direct sale (reed)
- Collective agreement (contract)

CHANNELS

- Water User Association
- Water bill
- On-site sale (reed)

CUSTOMER SEGMENTS

- Connected households in Drarga
- Farmers
- Buyers of reed grass

COST STRUCTURE

- Original capital investment
- O&M
- Opportunity costs (missed RRR revenues)

REVENUE STREAMS

- Household sewage fees
- Sale of wastewater, reed, co-compost (optional)
- Energy recovery (optional)

SOCIAL & ENVIRONMENTAL COSTS

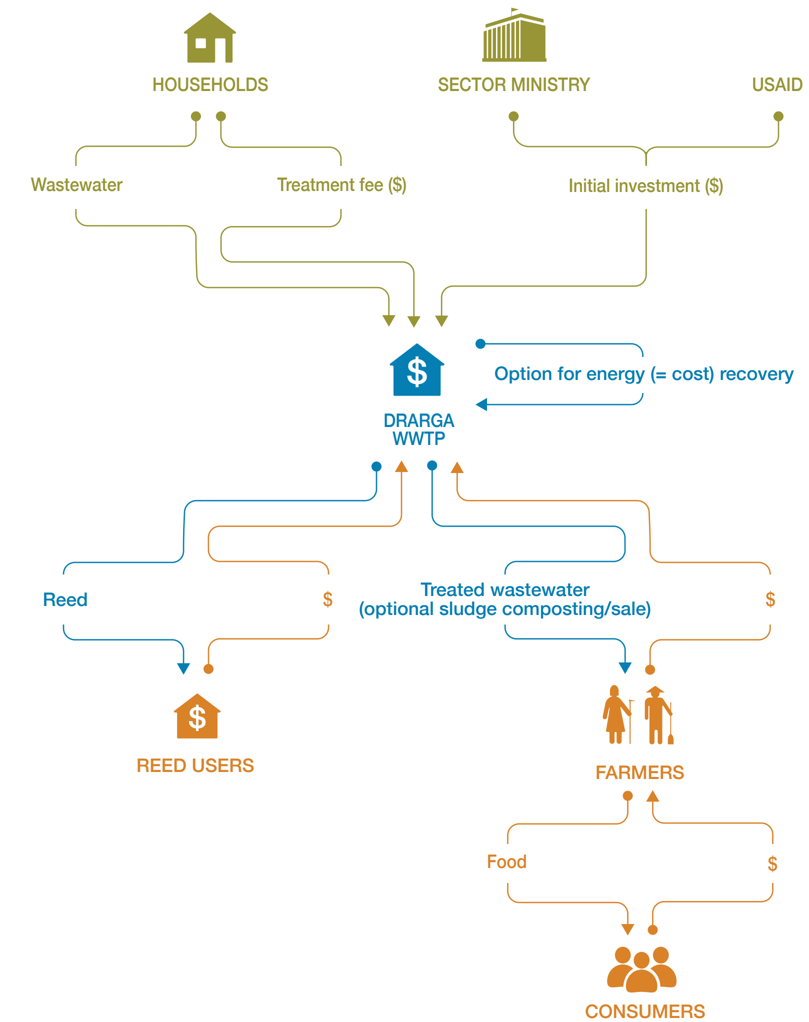
- Potential health costs for workers and consumers of irrigated crops if safety guidelines are ignored or plant performs below standard
- Potential environmental harm through plant flooding (wadi proximity)
- Potential of reduced farm income based on non-acceptance of wastewater use for food production

SOCIAL & ENVIRONMENTAL BENEFITS

- Much cleaner environment supporting town growth
- Likely reduction of human health-related costs due to reduction of pollution of streams and the aquifer
- Increased water and fertilizer savings if treated wastewater gets accepted, resulting in benefits for farmers
- Reduction in energy use (optional)

an area of about 6 ha of crops and about 2.5 ha of green spaces from 2005 on. However, these were mostly demonstration farms for accompanying research. Hirich and Choukr-Allah (2013) mention with reference to data from 2003 an area of about 16 ha under wastewater irrigation. From 2010 onwards, some water was also routed to neighboring crops under greenhouses. However, the actual reuse remained far below its potential (see overleaf).

FIGURE 215. BUSINESS PROCESS FLOW OF THE DRARGA WASTEWATER TREATMENT PLANT (WWTP)



Institutional environment

The original set-up of the plant was based on dialog and effective institutional partnerships with key stakeholders from the town and the Agadir region. Each stakeholder was responsible for some aspect of project implementation: the commune of Drarga provided the land for construction and initially owned the wastewater treatment facility; the Province of Agadir facilitated administrative procedures; the Al Amal Water User Association managed the plant; the Regional Agency for Planning and Construction (ERAC-Sud) financed construction of the main sewage collector, etc. This partnership was sealed through a collective agreement signed in 1998, under the patronage of the Ministry of Environment. A steering committee of stakeholders from different sectors supported the implementation process, and a technical oversight was formed to oversee the plant's operation, as well as the quality of agricultural products irrigated with treated effluents. The committee has the authority to stop the

delivery of treated water to farmers if monitoring analysis shows that the water fails to meet adequate reuse standards. The last institutional set up for the business was the establishment of an association of treated wastewater users in charge of maintaining the irrigation network, collecting fees, and distributing treated wastewater to its members. The project also assisted the Ministry of Environment to develop norms and standards for wastewater reuse, thus helped to support the enabling environment for replication and out-scaling (EAU, 2004).

Because of the limited financial and technical capacities across many smaller municipalities their wastewater treatment plants ceased over the years functioning which triggered a Governmental decision to gradually transfer from 2000 on the responsibility for sanitation in small- and medium-sized towns to the National Potable Water Agency (ONEP) whose mandate was amended to include sanitation (sewerage and wastewater treatment). According to Dadi (2010), lack of capacity was also a risk factor in the original setup of Drarga's WWTP, and in 2004, its ownership and operations were transferred to ONEP. ONEP was already involved in the Drarga project, including presiding over its technical committee. The commune of Drarga then requested ONEP to take over the management of the plant. This was a natural transition as also for replicating the Drarga model, the Drarga marketing plan had already recommended that ONEP becomes the "facilitator" or "dealmaker" (EAU, 2002). On the other hand, since agricultural water reuse is not within ONEP's mandate, interactions with farmers decreased, and so also efforts in the other resource recovery options. In September 2011, the National Electricity and Water Company (Office National de l'Electricité et de l'Eau Potable; ONEE), was created, with ONEP becoming its "water branch".

Technology and processes

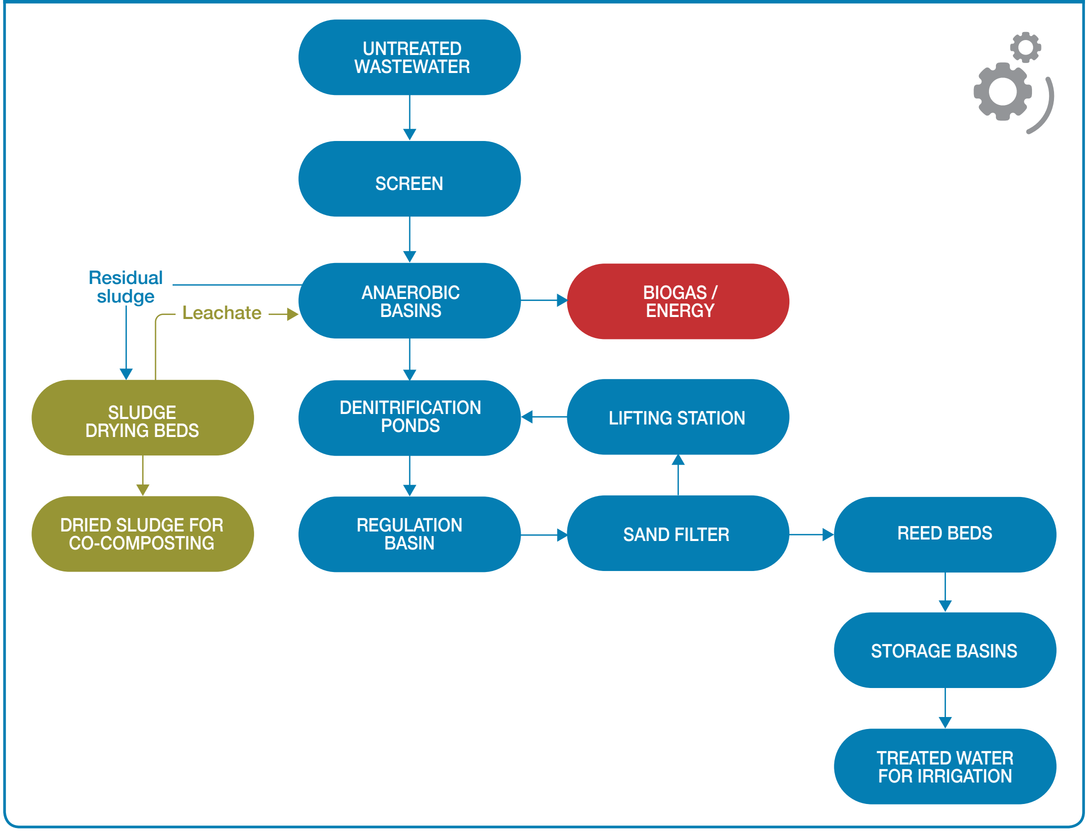
The plant provides advanced wastewater treatment with limited energy demands. After initial wastewater screening and grit removal, the wastewater is treated in two 918m^3 anaerobic basins with an average hydraulic retention time (HRT) of about three days. The flow is then sent to two 736m^3 denitrification ponds (HRT of 2.4 days) and finally to ten recirculating sand filters, each with a surface of 893m^2. After passing again the denitrification ponds, the effluent is treated in two 2,900m^2 planted wetlands (reed beds) before being assembled in storage basins (Young et al., 2011). The treated wastewater meets the WHO standards for unrestricted irrigation. When required, the water is pumped to irrigate farms, or drained into a local wadi. No chemicals or mechanical equipment are used in the treatment process; however, all equipment parts like valves and pumps were imported from USA which could make local replacement difficult (Dadi, 2010).

The Drarga plant was designed for the production of co-compost and energy: the residual sludge from the anaerobic basins can be pumped, dried (on three drying beds of 337m^2 each), and combined with organic wastes from the town to produce compost. Also the biogas from the anaerobic basins could be captured and converted into energy to run the pumps at the plant, thereby reducing its electricity costs (Figure 216). While the station started to collect methane gas in the anaerobic stage, and a generator was put in place, electricity generation was not realized (Dadi, 2010; Mohamed and Young, 2013). The generated sludge has been sent for drying beds and disposed on the local landfill without any reuse (100–120m^3 annually). Actual flow to the facility has been much higher (1,800–2,700m^3/day) than originally thought (600–1,000m^3/day). However, the influent has been more dilute than the plant was designed for and the plant continued to perform as expected (Young et al., 2011; Dadi, 2010).

Funding and financial outlook

According to the project, total investment in the Drarga wastewater treatment plant in 2001 was about USD 1.7 million with the equipment and construction constituting about 70% of total investment cost. Given the technology chosen, the annual O&M costs were estimated at USD 22,000 to 30,000 with

FIGURE 216. PROCESS FLOW OF THE DRARGA WASTEWATER TREATMENT PLANT[5]



electricity taking approximately 23% (Table 49). Considering also the data presented by Mohamed and Young (2013) a different assessment puts the annual O&M cost at USD 28,000 to 43,000.

Based on a treatment of 1,800m^3 per day (Young et al., 2011), the operator pays around USD 0.06/m^3. Households are provided with potable water consumption meters. At the end of each month, citizens pay an invoice that shows both potable water consumption and associated wastewater costs. The wastewater fee is about 20% of the water fee. The two lowest wastewater tariffs in 2010 were Morocaan dirham (DH) 0.51 and 1.28/m^3 and are the most common charged (Dadi, 2010). Using an average tariff of DH0.9 (USD 0.11/m^3 in 2010) the operator generates more revenues via the wastewater tariff than it has operational costs, even if not all households pay or an administrative overhead will be deducted.

Farmers were initially charged USD 0.05/m^3 for the treated wastewater. The other revenue streams which are included in the design, i.e. the one-time household sewerage connection fee, revenues from reed and compost sales, plus cost saving from internal energy production show the potential of this type of plant to achieve cost recovery even if some of the revenue stream did never crystallize (USEPA and USAID 2004). Before the plant's finance became part of ONEP's operations in 2004, the running costs appeared to be fully covered (Table 50).

Based on this simple accounting system, the combined revenues from the plant were at least initially deposited into a **special wastewater treatment plant account** that is independent of the city's

TABLE 49. ESTIMATED COSTS OF THE WASTEWATER TREATMENT PLANT IN DRARGA, MOROCCO

ITEMS	COST IN 1,000 DH	COST (%)
(a) Investment costs		
Research and Feasibility Study	3,000	14.8
Equipment	6,900	34.0
Construction	7,600	37.4
Monitoring	1,800	8.9
Reuse component	1,000	4.9
Sub-total	20,300	100
(b) Annual Operating Costs		
Electricity	60	23.1
Salaries	70	26.9
Laboratory Analysis	80	30.8
Miscellaneous	50	19.2
Sub-total	260	100

Note: USD 1= DH 11.4 in Dec 2001, and DH 8.4 in Nov 2004

Source: EAU, 2004.

TABLE 50. OPERATIONAL COSTS AND ANNUAL REVENUES AT DRARGA

USD	2001 (SECOND HALF)	2002	2003
Total income	49,820	59,760	61,560
Total expenses	18,250	28,180	43,180
Balance (net income)	31,570	31,580	18,380

Source: Mohamed and Young, 2013.

general budget. This dedicated account was further divided into two parts: the first part deals with **current account expenses** and the second part deals with the **extension and renewal account** in which money is saved to pay for the replacement of equipment and any future expansion of the wastewater treatment plant. This special arrangement was a response to common bottlenecks in public financing of O&M costs which contributed among other factors to the breakdown of about 70% of the wastewater treatment plants in the country (Choukr-Allah et al., 2005).

It is unfortunate that the full potential of the plant as a regional demonstration project for RRR remains to be verified (Dadi, 2010): neither the reed harvest and sale, sludge composting nor the biogas production took off. However, depending on local demand, all these options could be activated without any major additional investment. The main material to be recovered was water, and farmers' reservations showed a clear gap in the feasibility study. Especially to farmers whose products are exported to foreign markets, even "treated wastewater" still appeared 'unclean' and not good for their business, while raw wastewater that went through the ground or river before reaching the farm appeared acceptable for use even if this water is highly polluted (Aomar and Abdelmjid, 2002). Other farmers were unwilling to pay for wastewater that will anyway be discharged into the environment after treatment. Both factors undermined the generation of revenue from irrigation.[6]

Socio-economic, health and environmental impact

By eliminating the discharge of raw wastewater, the plant has significantly improved environmental and living conditions in Drarga, and reduced potential risks to aquifers and human health. Especially

high nitrogen levels entering the groundwater were of concern given the sandy nature of the soils. Construction of the plant has improved the living standards and value of local communities by eliminating problems associated with foul odors and mosquitoes. It has also supported water savings by promoting drip irrigation. Results from agricultural demonstration plots showed that the additional benefits for farmers (in particular savings on fertilizer) and the environment can be significant and could easily cover the irrigation water fee (EAU, 2004; Dadi, 2010). A note of caution refers (i) to the manual raking of the sand beds, which can pose an exposure risk to the employees; and (ii) the location of the plant next to a Wadi that is dry all year round but fills up to high levels during the rainy period and could potentially flood the plant (Dadi, 2010).

Scalability and replicability considerations

The Drarga wastewater treatment plant was designed as a demonstration plant for replication in small towns, with a strong emphasis on RRR and financial sustainability. Its planning and setup was based on strong stakeholder participation and included a dedicated self-marketing strategy for national replication of the model under the facilitation of ONEP (EAU, 2002). The strategy included demonstrations, also of financial viability, capacity development as well as various communication components. Key drivers which supported calls for replication were:

- High treatment standard based on applied technologies with a favorable cost effectiveness.
- Multiple opportunities to achieve O&M cost recovery.
- High environmental and social benefits.

FIGURE 217. SWOT ANALYSIS OF DRARGA BUSINESS CASE, MOROCCO

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES

INTERNAL ORIGIN
ATTRIBUTES OF THE ENTERPRISE
	STRENGTHS
	▪ Full O&M cost recovery based on:
	  ▪ Low cost treatment
	  ▪ Multiple cost recovery mechanisms
	▪ Participatory planning and operation
	▪ Special account for costs and revenues
	▪ Visible environmental benefits
	▪ Significant profit opportunities for farmers using wastewater
		WEAKNESSES
		▪ Insufficient awareness creation to address farmers' unwillingness to pay
		▪ Limited local expertise in running of the plant and its RRR options
		▪ Centralized management de-emphasizing RRR given cost recovery via the water bill

EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Awareness creation for the reuse of tertiary treated water for the creation of financial and economic value ▪ High potential for (so far neglected) energy recovery and organic fertilizer production ▪ Development of reuse policies based on the example ▪ Indirectly charging farmers for the treatment via the land rent in locations where farmers would not accept paying for the treated water	**THREATS** ▪ Backlash from consumers and importers of wastewater irrigated crops ▪ Replication requires towns with sewer systems ▪ National promotion of water reuse remains lip service without awareness and demand creation

The business case demonstrated that high cost recovery could be achieved where demand allows to capitalize on the different revenue streams the plant offers. While the environmental and social benefits of the plant were fully achieved, it might require more water stress or higher (pumping) electricity prices to see water reuse and energy recovery going to scale.

Summary assessment – SWOT analysis

The inspirational setup of the Drarga plant was featured in the 2004 *US EPA - USAID Guidelines for Water Reuse*. The close stakeholder involvement and joint design with water users has been praised and can be considered an excellent example of "Design for Reuse" as demanded by Murray and Buckley (2010). Although resource recovery faced in Drarga some challenges, the case main strength remains the combination of low setup and operational costs with multiple options for operational cost recovery. The challenges Drarga is facing are common also in other regions, which again makes it a good example. Farmers asked, like also in Pakistan's Faisalabad, why to pay for a product which will anyway be released. Others feared less (export) demand for their produce, based on the term 'wastewater' while highly polluted stream water would be without this terminology stigma.

The local demand for compost, reed, as well as plant-internal electricity generation remained underexplored, partly related to the change in plant ownership and operation which resulted in less emphasis in the demonstration of alternative cost recovery options via RRR. Figure 217 illustrates the full SWOT analysis of this business case based on the available information.

Contributors

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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014/16. As business operations are dynamic, data might change.

Notes

1 In 2011, the National Potable Water Agency (ONEP) was regrouped with the National Electric Utility (ONE) to become the National Electricity and Water Company (Office National de l'Electricité et de l'Eau Potable or ONEE).

2 Since 2002, Ministry of Environment and Water, and since 2007, Ministry of Energy, Mining, Water and Environment.

3 A renewable water supply below 1,000m^3 per capita per year has been suggested as a threshold for water sarcity, based on estimates of water requirements in the household, agricultural, industrial and energy sectors, and the needs of the environment (Rijsberman, 2006).

4 The majority of treated wastewater is used on golf courses (66%) and for industrial reuse (20%). About one percent supports groundwater recharge. While the area under wastewater irrigated farming varies between sources (550 ha–max. 2,000 ha), there are estimates of additional 6,000–7,000 ha under informal irrigation with untreated wastewater (Bahri, 2008; MEMEE, 2013; Salama et al., 2014; www.fao.org/nr/aquastat/).

5 Energy and biomass (compost) recovery optional and not realized so far.

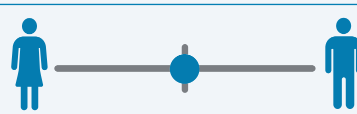
6 An opportunity to charge farmers indirectly for the treated water could be through owing and renting out farmland along the effluent channel or stream. As shown in Pakistan, the availability of wastewater can significantly increase the land value even above the one next to freshwater canals (van der Hoek et al., 2002).

BUSINESS MODEL 17

Wastewater for greening the desert

Pay Drechsel and Munir A. Hanjra

Key characteristics

Model name	Wastewater for greening the desert
Waste stream	Domestic wastewater from decentralized sewer systems
Value-added waste products	Treated wastewater and sludge (biosolids); wood and other tree products
Geography	Arid and semi-arid regions (e.g. MENA)
Scale of production	Small to medium (300 to 30,000m^3/day reused)
Supporting cases in this book	Cairo, Egypt; Ouardanine, Tunisia; Drarga, Morocco
Objective of entity	Cost-recovery [X]; For profit [ ]; Social/environmental enterprise [X]
Investment cost range	Treatment plants: up to USD 50 million Agroforestry system: USD 300,000 to 1.6 million
Organization type	Public or public-private or for the reuse component also only private
Socio-economic impact	Green infrastructure like urban and peri-urban tree plantations have multiple financial and economic benefits from wood and fruit production to water retention, pollution combatement, job creation along the value chain and locally increasing property values
Gender equity	Gender specific advantages vary along the water reuse value chain 

Business value chain

The basic business concept is to recover in arid and semi-arid regions as much treated wastewater as possible for landscaping and productive reuse, like afforestation for timber, fuel or fruit production, while minimizing the unproductive or environmental harmful discharge of water and sludge. Given that treated wastewater of suitable quality for tree plantations will anyway be produced, or is already available, the additional value proposition for the creation of green infrastructure in a desert environment will have multiple social, environmental and economic benefits including improved overall living conditions while having the potential for recovering its own costs through the creation of opportunities for economic growth along the reuse value chain.

The treatment plant might be run by the public and/or private sector and has to be located at the border of a town or city with sufficiently available land for afforestation, recreation or agriculture in the vicinity. The high value for environment and society will help to sustain public subsidies, allowing the business to focus on the recovery of the additional reuse-related costs. For a high reuse rate and limited water conveyance (pumping), decentralized small to medium-sized wastewater treatment

plants serving towns, peri-urban communities, suburbs and emerging cities would be most favourable. The institutional set-up across the sanitation-agriculture interface is important as all three case studies showed, and requires a high level of participatory planning and trust building for the recipients of the treated wastewater as well as their customers in its safety. The business model is most promising where no alternative water sources are available and the technology and safety standards permit the production of crops or produce in high demand. The model is at risk of limited impact where a) regulations are too weak; or b) do not match locally feasible technologies; and/or c) alternative water sources are available at a lower or even slightly higher cost.

Next to the sale of treated wastewater, also treated sludge (biosolids) can generate revenues as soils in dry areas are generally poor in organic matter and sludge could be an excellent soil ameliorant supporting soil fertility management and its water holding capacity. However, sewage sludge, even more than the treated water, requires a very reliable monitoring of potential contaminants. If these are too high, sludge can still be an asset but for other uses than food production. With the right institutional set up, market research, sales strategy and a pricing policy, net profits from the reuse scheme are possible.

The business concept involves a simple value chain schematic as shown in Figure 218. This treatment-reuse scheme can result in a public private partnership or remain in the public sector.

Business model

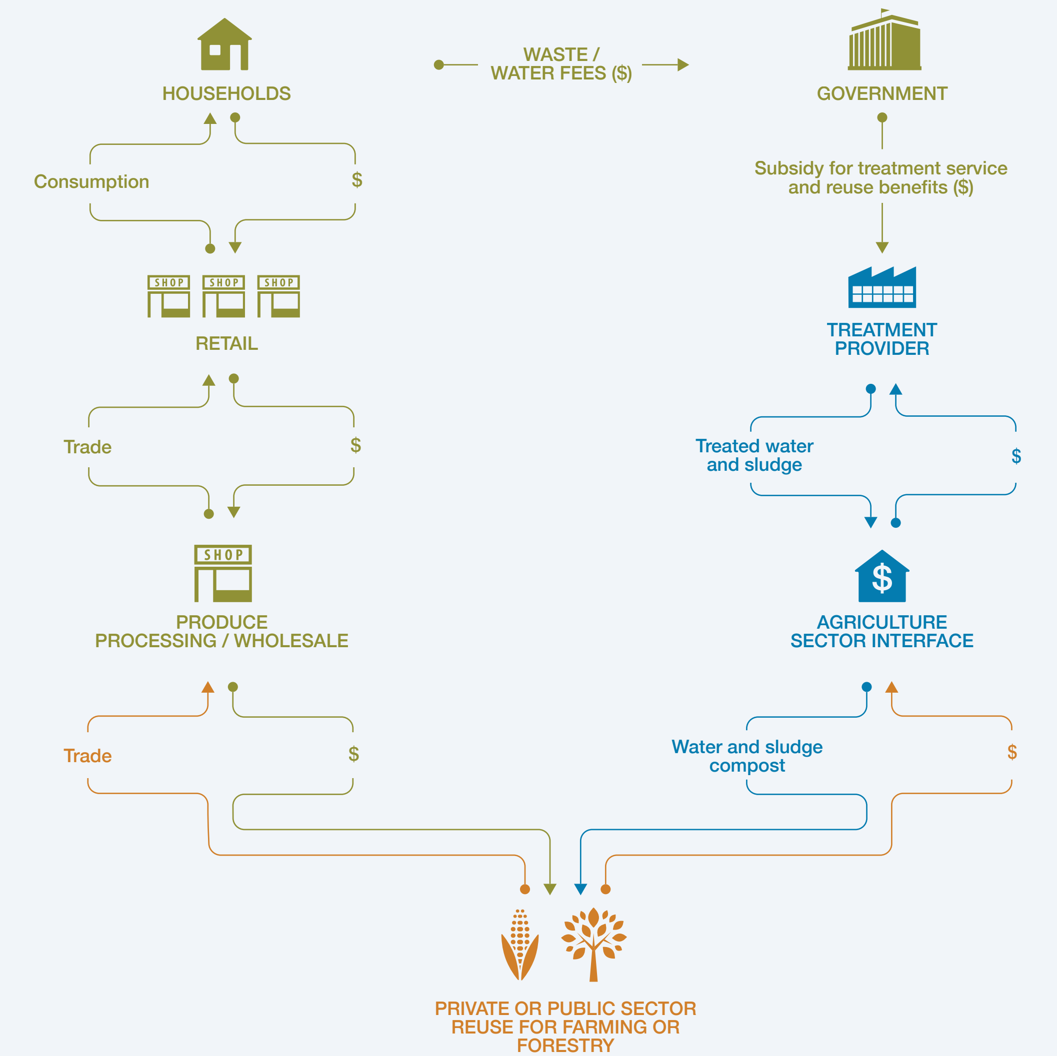
The basic value proposition of the model depends on the business goals and social objectives of the entity initiating the business model – government or private entity operating the wastewater treatment system, and government or farmers/ private enterprise operating the reuse system. Eventually the model will have several value propositions, but with different emphasis for cost recovery. **Next to the treatment of wastewater for safeguarding public health and other water resources, the second value proposition is to establish green infrastructure by offering water, crop nutrients and soil organic matter.** This will result in amenity values and other ecosystem services. Improved soil productivity can for example support tree or fruit plantations, wood and cotton production, biofuel, fodder or also vegetables as long as possible health risks can be minimized and controlled.

There are many institutional options for running the model. Two examples are:

a) Treatment plant and tree plantation are managed by the same public company. With free water and land allocation, cost recovery for the reuse component will largely depend on the efficiency of reducing operational (e.g. electricity) costs and possible overstaffing. Extending the privileges of free land and water to the private sector, would certainly constitute a strong incentive for its engagement assuming trees/crops with high market value and short turnover can be grown.
b) Alternatively, the responsibilities between treatment, water transport and reuse are shared between different stakeholders, which can be public or private like in the Tunisian case where water is sold along its pathway and each entity is using different strategies for cost recovery.

The key revenue sources for the treatment plant are (i) households via sanitation fees, usually collected as part of the water bill; (ii) governmental subsidies reflecting the treatment service for society and nature; and (iii) direct or indirect income from the sales of forest/tree crop products (Figure 219). For the conveyance of the treated water to the plantations, both the treatment entity and the government (saving directly/indirectly water disposal costs), and the benefitting water user association should contribute. A target could be to align wastewater selling rates with the operational cost of the water transfer and the market value of the irrigated product. Another possible revenue stream could derive

FIGURE 218. VALUE CHAIN SCHEMATIC – WASTEWATER REUSE FOR AGRICULTURE AND FORESTRY



from carbon sequestration in forest plantations or orchards (Box 8). While investments in perennial plants, like trees for wood production or evergreen citrus trees can absorb water year-round, their payback period till the first harvest (for fruits at least three to five years, for wood production twice as long) does not support quick returns on investment. In such cases, such trees might best be combined with other crops allowing earlier revenues. Many farmers call in particular for advanced treatment to grow highly profitable cash crops like vegetables.

FIGURE 219. BUSINESS MODEL CANVAS – WASTEWATER REUSE FOR GREEN INFRASTRUCTURE IN (SEMI)ARID REGIONS

KEY PARTNERS

- Sector ministry
- Agroforestry systems (managed by public or private sector)
- Served households
- Authorities in charge of safety monitoring
- Larger public (trust building)
- Environmental ministry/authority

KEY ACTIVITIES

- Treatment and sale of wastewater and sludge
- Collection of household fees (sanitation tariff)
- Social marketing to support perceptions on reuse safety

KEY RESOURCES

- Treatment plant
- Wastewater with no or limited industrial contamination
- Land, labor and capital investment
- Partnerships with agricultural sector

VALUE PROPOSITIONS

- To build green infrastructure and value chains from treated wastewater and sludge (biosolids)

CUSTOMER RELATIONSHIPS

- Government to government
- Government to water user associations/ private sector
- Online household billing
- Direct sale of biosolids to traders (or farmers)

CHANNELS

- Direct dialog and contract (water/biosolids reuse)
- Wholesale contracts (if treatment plant operator also runs plantation)
- Online communication with served households

CUSTOMER SEGMENTS

- Water user associations
- Golf courses
- Forestry projects
- Cotton plantations
- Orchards
- Biofuel and energy market
- Soil input dealers

COST STRUCTURE

- Capital investment (treatment plant, water to farm conveyance)
- Operation and maintenance costs (incl. in-house quality monitoring and costs of risk prevention)
- Customer interface and social marketing/promotional costs

REVENUE STREAMS

- Sewage tax for connected households
- Government subsidy (environmental and social benefits)
- Sale of forest products, wastewater and sludge
- Energy savings (via internal (treatment plant) energy recovery)
- Carbon sequestration (potentially, see Box 8)

SOCIAL & ENVIRONMENTAL COSTS

- Limited costs if treatment plant can avoid receiving untreated industrial effluents, treatment level is appropriate and monitored, and compliance with safety protocols strictly enforced.

SOCIAL & ENVIRONMENTAL BENEFITS

- Green infrastructure benefits from ecosystem service support, like water and nutrient cycling, micro-climate improvement, amenity values, jobs along the value chain, and editable or non-editable (e.g. firewood) produce
- It reduces the disposal of treated but nutrient rich wastewater into natural water bodies
- Reduction in energy use (optional)

Alternate scenario

Greater cost recovery through better accounting, pricing and market extension

As seen in the example of the Drarga plant near Agadir in Morocco, an advantage of decentralized plant management can be that for each plant's service area, all sales revenues and revenues from the water or sewage tariff are deposited into a special account, independently of others accounts, to serve solely the cost-recovery and maintenance of each individual treatment plant. This system can prevent that community revenues are redirected to other needs, and could also provide incentives for benchmarking where management is centralized if transaction costs can be minimized.

Greater cost recovery could come through improved pricing of the services, resources and products. For instance, household could be charged block rates prices for wastewater treatment based on actual water usage, instead of a flat sewage tax as it is common in some countries. Treated wastewater could be sold in bulk to the water user association at a price that reflects more on the costs of water treatment rather than just the additional cost of the water conveyance between treatment plant and irrigation system. The farmer body could then resell the water to its members charging them a markup to recover additional costs of operations including routine maintenance and repairs within the irrigation system. However, all this requires that farmers have limited access to other water sources.

Increasing the freshwater tariffs would make agricultural irrigation with freshwater unfeasible and might force farmers to shift to using reclaimed wastewater if its tariffs are maintained low and if its supply and quality are reliable. This incentive might be constrained by the fact that many farmers control their own facilities for meeting their needs from groundwater resources; thus, energy tariffs should also be considered to steer pumping costs.

For further income, new market segments are needed, like industrial demand for dried sludge as fuel. To reduce the industrial carbon footprint, especially in the cement industry, or where conventional fuel sources are in irregular supply or expensive, sewage sludge derived kiln fuels can be an alternative which the industry might favor as it will in addition qualify under the Clean Development Mechanism (CDM, Box 8).

Box 8. Forest carbon offset: An additional revenue stream?

Converting 'no forest' desert land into a 'forest' absorbs carbon in the growing wood which can be sold on the carbon offset market to carbon emitters, and add a revenue stream to the wastewater reuse project. The gain depends on the total carbon offset which is estimated in 'million tonnes equivalent' (mt CO_2-eq.) stored in living tree biomas. In 2012, a cumulative 134Mt CO_2e of offsets have globally been transacted from 26.5 million hectares of forests. Two out of every three offsets were sold to multinational corporations. Businesses were motivated by offset-inclusive corporate social responsibility (CSR) activities, or to "demonstrate climate leadership" in their industry or to send signals to regulators. Demand for offsets from afforestation or reforestation projects were in 2012 with 8.6 MtCO_2e at a similar level as demand based on *reduced emissions from deforestation and forest degradation* (REDD).

The issuing of carbon credits for afforestation activities has to meet a set of strict guidelines. The amount of carbon sequestered by forests has to be assessed and depends upon many factors including type of tree, tree age and local growth rate, which again depends on climate, irrigation and soil quality.

If a forest owner sells his forest then (s)he is committing to maintain the CO_2 stock. If wood gets lost, like to climate events, disease or unplanned instead of planned harvest, the owner would have to buy back offset credits to cover the loss. An 'ideal' carbon sequestration forest is one where the owner is able to sell carbon credits each year until tree growth and the carbon sequestration rate plateaus, at which time the forest could be harvested and the harvest revenue is higher than what is needed to pay for the lost (above ground) carbon stock. This requires close monitoring of the wood and carbon markets. An alternative target would be to establish a sustainable rotation with regular planting and harvesting, where the stock and growth rate of sold forest biomass could be maintained despite harvests.

Obviously, this type of management and certification has costs and the question is if the returns make them worthwhile. From a purely financial perspective, revenues from offsets in today's still-developing offset market are limited. The price per ton of CO_2e varies significantly but is commonly in the range of USD 4–10, although higher and lower prices can be found. Trees might bind five to ten metric tons of CO_2 per ha per year which translates on average into an annual gain of about USD 30–80 per ha. Thus a 50 ha irrigated wood plantation could generate a gross annual income from carbon sequestration of about USD 1,500–4,000 which has to be compared with the transaction costs of registration and alternative commercial options (timber, firewood, fruits, etc.). Orchards are in the carbon business less prominently as they are usually less densely planted and also pruned, i.e. their carbon accumulation rate will be lower than of many forest species. The plantation sizes as reported in our two case studies are rather small and as offset credits are often traded in units of 10,000t $C0_2$e or more, which might only be achieved on about 1,000 ha, forest owners need to pay an Offset Aggregator who functions like a broker between woodland owners and the carbon market. A possible alternative for the future could be other offset markets, such as BioBanking where plantation owners can sell Bioversity credits to the market as seen e.g. in Australia (NSW 2007) or payments for watershed services (The Rockefeller Foundation 2015).

Additional sources: http://www.rogerdickie.co.nz/Forestry.aspx; www.forestcarbonportal.com/; www.ecofys.com/files/files/world-bank-ecofys-2014-state-trends-carbon-pricing.pdf.

Potential risks and mitigation

The business model presented here was designed based on the analysis of three case studies in Tunisia, Egypt and Morocco, and other cases and references. There can be a variety of business risks affecting the successful implementation of such a model, most of them being more generic than model specific. For example, as reuse projects involving wastewater are potentially harmful to human and environmental health, particular health risk (mitigation) options are obvious and have to be highlighted.

Market risks: There is no risk related to the need for treating the wastewater, which is a necessity for safeguarding public health. Market risks exists however for the reuse part of the system, which can derive e.g. from (i) competing water/fertilizer sources; (ii) competing final products; and (iii) lack of trust in product quality.

i) Lower costs for accessing alternative water sources (e.g. groundwater) or organic fertilizer can reduce demand for reclaimed water or sludge as fertilizer.
ii) If imported fruits or timber have an established local market, market penetration will require extra efforts or highly competitive pricing which reduces the likelihood of cost coverage.

iii) Different kinds of reuse like irrigating trees, orchards, fodder or vegetables will require different water quality standards. It is mandatory that treatment and post-treatment options will meet these standards to maintain trust in the reclaimed water. Monitoring compliance with safety measures and final water effluent are part of the risk management protocol, as outlined in the WHO *Sanitation Safety Planning Manual* (WHO, 2015). However, technical capacity alone might not be sufficient to address negative consumer perceptions. Any reuse project requires active stakeholder engagement, transparency and feedback from the start on. The role of social marketing and awareness raising can be critical in reducing opposition to water reuse especially in agriculture.

Technology performance risks: A large variety of treatment technology and irrigation systems are available. In low-income countries, common reasons for low or decreasing technical performance in wastewater treatment are poor maintenance practices often due to lack of incentives, lack of electricity, or e.g. lack of sufficient water to flush the sewers. Poor maintenance can result in non-compliance with set treatment standards, which can translate into health risks and loss of customers. Also irrigation technology can have shortcomings, especially where wastewater has to pass in small tubes, like in drip irrigation, where clogging is more common than with fresh water.

A mismatch between imported treatment technologies and local requirements, possibilities and capacities has also been described, for example by Nhapi and Gijzen (2004) from Zimbabwe and supports the call for low-cost applied technologies (Libhaber and Orozco-Jaramillo, 2013) with any additional treatment levels matching cost-effectively the intended reuse or disposal.

Political and regulatory risks: These risks vary from country to country and can be high where the regulatory frameworks, like reuse standards, are under discussion or managed by different authorities with overlapping responsibilities.

Social equity related risks: The model is considered in general as neutral in view of particular gender advantages or disadvantages from the operational or business perspective. As the percentage of women graduating in both, agriculture/forestry and engineering in MENA countries is comparable to or higher than in more developed countries, the foundation for women employment in treatment plants or forestry is increasing. However, women's increasing enrollment in engineering and the sciences is not (yet) reflected in a higher female labor force participation or lower female unemployment (World Bank 2009). There are significant variations between countries, and there can be more permanent employment opportunities for men in forestry and wood processing, while the forest might provide firewood as primary or secondary objective, which could be a significant social benefit in an environment where women struggle finding fuel. There is also evidence of seasonal employment opportunities for women (e.g. olive harvest in Tunisia), although in many countries female workers receive lower wages than male.

Safety, environmental and health risks: Wherever wastewater is used there can be a health risk for different stakeholders and the environment, including occupational risks for workers, discomfort (odor) affecting communities in plant vicinity, and depending on what is produced also risk for buyers/consumers. Mitigation measures are ideally installed along the wastewater treatment to reuse value chain (WHO multiple barrier approach). To minimize safety and health risks to workers and other stakeholders, standard protection measures are required as elaborated below (Table 51). Among various reuse options, growing trees is considered one of the safest. However, where trees are harvested for editable products for the market (e.g. citrus, olives), care has to be taken that pathogens do not get in contact with the harvested product. A particular challenge derives from the use of wastewater and sludge (even if composted, i.e. sanitized) where the wastewater includes industrial effluent due to the possibility of heavy metal entering the food chain. As in all cases of industrial effluent,

local pretreatment is required before the water enters the public sewer network and eventually the treatment plant. The risk would matter less for wood than fruit production where it requires monitoring. Although in the target areas aquifers are usually only found in considerable depth, regular groundwater monitoring is also required.

TABLE 51. POTENTIAL HEALTH AND ENVIRONMENTAL RISKS AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 17

RISK GROUP	EXPOSURE						REMARKS
	DIRECT CONTACT	AIR/ DUST	INSECTS	WATER & SOIL	FRUIT	WOOD	
Workers							Sanitation Safety Planning (WHO 2015) recommended for entire value chain. Elevated risk if business opts for sewage sludge composting/sale.
Farmers							
Community							
Consumer							
Mitigation measures				Pb Hg Cd	Pb Hg Cd		

Key: NOT APPLICABLE | LOW RISK | MEDIUM RISK | HIGH RISK

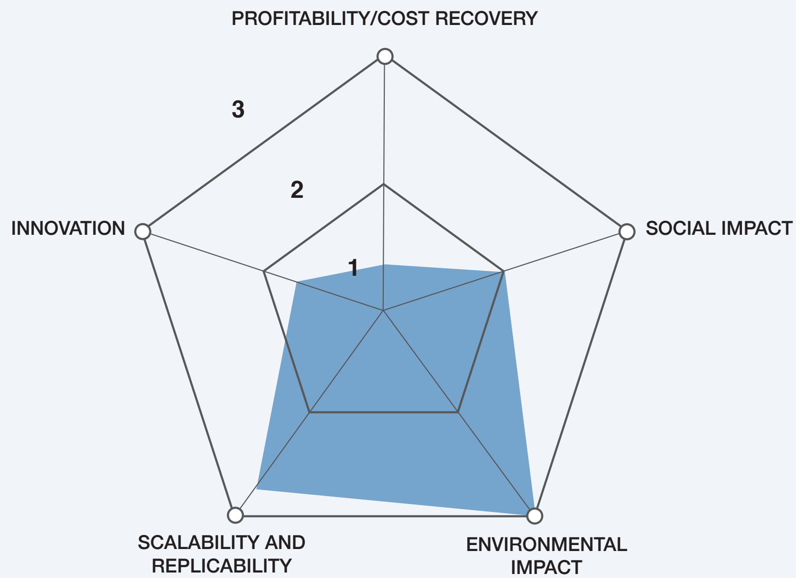
Business performance

Wastewater reuse to produce green infrastructure in human vicinity like tree plantations, parks or orchards can have significant social and ecosystem benefits in MENA region (Figure 220), although the overall social impact varies to some extend with the generated employment opportunities.

Using wastewater for wood production is one of the safest and financially promising reuse options. Thus from an investment perspective, stigma might be less an issue, and the main challenges of the model are more related to the time span between investment and payback, not the water itself. However, there are various options from fast growing trees to agro-forestry which can allow faster returns if supported by treatment quality and regulations.

Different ownership models are possible with cost recovery for the treatment plant largely depending on the freshwater and wastewater tariffs and prices. As long as freshwater is sold under value, the business model ranks low in view of recovering treatment costs although it reduces the water bill of the plantation, and can create significant financial value in form of wood and other forest products. The model ranks high in its adaptability to various bio-physical conditions and in terms of scalability and replicability wherever land is available and freshwater sufficiently scarce that farmers have no alternative. The model can work with plants of any size providing secondary treatment although the cost recovery share might be highest at the scale of smaller towns or suburbs. The right institutional setup to balance financial and economic benefits to the satisfaction of all involved parties is the challenge.

FIGURE 220. RANKING RESULTS FOR WASTEWATER REUSE IN AGROFORESTRY SYSTEMS



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15. BUSINESS MODELS BEYOND COST RECOVERY: LEAPFROGGING THE VALUE CHAIN THROUGH AQUACULTURE

Introduction

According to Global Water Intelligence (GWI 2010) the market for water reuse is on the verge of major expansion, outpacing desalination. Especially capital expenditures on advanced water reuse are expected to grow significantly. The market will migrate away from irrigation, towards the production of water, which passes the quality requirement of industrial clients, and for potable reuse based on microfiltration, reverse osmosis and advanced disinfection. Despite being a more expensive process, this water reuse can provide better returns on investment.

Less sophisticated treatment options can also provide high-value products, especially if the reclaimed water is used for the production of more than crops such as animal protein. If such a value proposition can be based on low-cost applied technology, it would have a significant replication potential across low-income countries and/or where advanced treatment facilities have a limited lifetime. It would also be able to attract the local private sector where limited investment costs can be combined with high returns on investments. The examples presented in this chapter are based on aquaculture. Aquaculture-based models recycle water and also assimilate nutrients into the food chain. While in some models, like in the large-scale case of Calcutta (Bunting et al., 2010), fish are produced within the (natural) treatment system, in other cases fish are grown in the last pond of a constructed treatment system, or aside the treatment system which is producing fish feed. The feed consists of fast growing plants which are extracting nutrients from the water and contribute to its treatment (phyto-remediation). Although wastewater-fed aquaculture is according to Bunting et al. (2012) on the decline due to factors such as reduced availability of peri-urban land and increasing water contamination, aquaculture in general is considered as the fastest growing agricultural sector in the world (World Fish Center, 2011). It can be particularly attractive where fish is in high demand, land available and water sources do not pose particular health risks.

This chapter describes two cases of wastewater reuse in aquaculture in **Bangladesh** and **Ghana**. The first case looks at a wastewater system in the town of Mirzapur, Bangladesh, which generated over 20 years profit until the treatment system was phased out. The second case reviews the system pioneered by Waste Enterprises Ltd. in Kumasi, Ghana. In Mirzapur, protein-rich duckweed was produced in wastewater treatment ponds and fed to fish in adjacent ponds, while in Kumasi, the treated wastewater was used directly for fish production. The two examples are followed by **Business Model 18: Leapfrogging the value chain through aquaculture**, which showcases the possibility of a win-win situation for public-private partnerships that are able to cover operational costs as well as recover capital costs within an acceptable time frame.

As with the other chapters, these examples do not claim to be comprehensive and some better cases could have been missed due to information and time constraints. However, they show significant opportunities for moving reuse solutions beyond cost recovery to net profits for business by combining a relatively low-cost but highly efficient technology with an advanced value proposition. This is a remarkable achievement in the usually highly subsidized wastewater treatment sector.

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CASE

Wastewater for the production of fish feed (Bangladesh)

Pay Drechsel, Paul Skillicorn, Jasper Buijs and Munir A. Hanjra

Supporting case for Business Model 18	
Location:	Mirzapur, Bangladesh
Waste input type:	Hospital complex-derived raw wastewater
Value offer:	Protein-rich feed to cultivate whole, fresh fish – carp species, and treated wastewater
Organization type:	Partnership of private trust and NGO
Status of organization:	Fully operational since 1993; phased out in 2013–2015
Scale of businesses:	Medium
Major partners:	PRISM Bangladesh / Kumudini Welfare Trust (KWT)/ Kumudini Hospital Complex (KHC)

Excutive summary

The for-profit business case describes the experience in Bangladesh to locally treat wastewater for fish production and crop cultivation, generating over 20 years net profits and improvements in environmental quality. The business known as 'Agriquatics' started full operations in about 1993 and run till about 2015 when the treatment system was decommissioned and replaced. The system at the town of Mirzapur received raw sewage and grey water from the local Kumudini Hospital Complex (KHC), water which would otherwise flow untreated to a nearby river. The treatment involved duckweed-based phytoremediation on a 0.6-hectare zig-zag plug flow. No fees were charged for the treatment, no subsidies received from the government and no water sold, but fish was reared on the harvested duckweed in adjacent tanks fed by groundwater and topped up with treated wastewater. Perennial crops such as papaya and bananas were grown along the pond perimeter providing additional income. The fish and crops produced were sold on-site and the income received did not only cover operational and maintenance costs of the combined system, but also recovered several times the original capital investments.

KEY PERFORMANCE INDICATORS (AS OF 2012)	
Land use:	1.6 ha
Wastewater treated:	ca. 300m^3/day
Capital investment:	USD 20,000 for the plug flow treatment system, of which 32% as loan for land development and equipment; and 68% long-term land lease
Labor:	4-persons for 1 hour each day – 7 days per week (0.7 full-time equivalent)
O&M cost:	The major O&M costs were harvesting and feeding the duckweed to fish, fish harvest, and seasonal cleaning of the fish tanks. No chemicals were required

Output:	About 7.5 tonnes/yr of mixed carp species fish sold on-site at an average price of USD 1/kg, earning USD 7,500 from fish (an equal amount possible pilfered) and about USD 1,000 from crops. With costs deducted the annual net revenue was around USD 2,000–3,000					
Potential social and/ or enviornmental impact:	Several part time jobs, inexpensive source of fish and a non-chlorinated treated effluent that meets US advanced tertiary standards (Alaerts et al., 1996)					
Financial viability indicators:	Payback period:	6 years (loan); less than 10 years all	Post-tax IRR:	26%	Gross margin:	20%

Context and background

Mirzapur town (ca. 28,600 inhabitants) in central Bangladesh is well known to the community for the Kumudini Welfare Trust (KWT) and its hospital complex with college and schools. This is also where the *Shobuj Shona* system – continuous duckweed farming and feeding to mixed carp species – for wastewater treatment was first developed. Initially, the local hospital had a four-cell facultative wastewater treatment system but this proved over time inadequate. The KWT contacted PRISM[1], an NGO that had a rural development and healthcare project in the area, and in a collaborated effort it was agreed to build, operate and manage a *Lemnaceae*[2] (duckweed)-based wastewater treatment system which supports fish farming on the condition that the operating entity would keep any profits that the system might generate. The development of duckweed-based, conventional wastewater treatment began in the 1980s with the finally installed plug flow system for the hospital complex starting full operations in 1993 (Gijzen and Ikramullah, 1999; UNEP, 2002). The interlinked aquaculture system continued over the years to supply the local Mirzapur population with a reliable, twice per week harvest of carp and free of charge wastewater treatment service for the local hospital, schools and staff housing complex.

Market environment

Situated on the banks of a largely perennial river, and with water still being relatively abundant in the Mirzapur area, there is no demand for (treated) water, but fruits and in particular fish which provides in Bangladesh more than 50% of total animal protein intake (FAO, 2014a). Agriquatics therefore adopted the Shobuj Shona system of duckweed farming to produce a protein-rich fish feed for its own aquaculture system and revenue generation. Despite a boom of aquaculture in the country, the large Dhaka city market is absorbing a huge share of what gets produced by formal aquaculture operations, allowing Agriquatics to focus on local demand. Fish sale was complemented by the production of fruit and vegetables including bananas and taro around the ponds. According to Gijzen and Ikramullah (1999) a substantial portion of the fish produced was bought by the Kumudini Hospital Complex (KHC), which reduced costs for distribution and marketing, and pressure from competitors in Mirzapur. The opportunity that Agriquatics exploited was the combination of the need for the treatment of wastewater, and the locally strong demand for fish, combined with the low-cost availability of land and potential fish tanks.

Macro-economic environment

Bangladesh ranks for many years globally among the top five countries in view of aquaculture production (FAO, 2014a). Aquaculture has been one of the fastest-growing economic subsectors of the economy, providing high-protein food, income and employment and earning foreign exchange. More than 4 million fish farmers, mostly small-scale, and more than 8.5 million other people derive a livelihood from it directly or indirectly. In 2012, farmed fish contributed some 1.73 million tons to the

country's total fish production of 3.26 million tons (FAO, 2014a). This is an almost 19-fold increase from the 1980 aquaculture production of about 91,000t, and for example ten times the reported production in the USA. Export revenue in 2012 was estimated at USD 450 million (FAO, 2014b).

The macro-economic situation reflects a positive business driven investment climate for aquaculture in Bangladesh. However, Edwards (2005) and Parkinson (2005) stated that direct governmental support, institutional assistance and a lack of a national funding mechanism to support, e.g. the capital investments in aquaculture in general, or duckweed-based systems in particular are missing. This might be changing under the National Aquaculture Development Strategy and Action Plan 2013–2020 which is aligned with and draws guidance from the National Fisheries Policy, Country Investment Plans, the National Fisheries and Livestock Sector Development Plan and the preceding national fisheries strategy and action plan of 2006–2012. The new plan is however not addressing linkages between sanitation and aquaculture and leaves the model Agriquatics pioneered in a grey area, even more as also wastewater management and reuse are typically not acknowledged as a major element of water management in existing laws and policies in Bangladesh. The sector is hampered, in addition, from a considerable complexity with regard to the power of implementing authorities from both the agricultural and urban wastewater management perspectives.

Business model

The overall value proposition is high quality wastewater treatment paid through the production of fish feed, crops and fish at competitive market prices, making the system independent of fees and tariffs. The enterprise employs a value-driven and for profit, end-sales model whereby an even larger value derives from environmental and social responsibility impacts beyond sales revenues (Figure 221). Essential for the business model start-up was the partnership of the Hospital (via Kumudini Welfare Trust) and PRISM Bangladesh, enabling expertise-supported and cost-effective implementation of the duckweed water treatment and fish rearing system. This ensured that two important economic values were created: (i) wastewater that is treated to an advanced tertiary level at no extra cost to the hospital and thus adding value for the hospital in terms of avoided costs for financing an additional treatment level; (ii) a reliable and guaranteed supply of wastewater generated fish feed at no extra costs, and high quality water supporting crop and fish farming. The symbiosis between the non-profitable wastewater treatment and the highly profitable fish production made the Agriquatics model financially viable, not only to break even, but to pay back the initial loan taken for the setup of the treatment system.

PRISM inherited a defunct pond system which was redesigned for fish production while its capital investment went into the duckweed zig-zag treatment system (see below). Land, fish tanks, water and nutrients were effectively free. Since conventional fish feed is scarce and (consequently) prices are high, the use of alternative sources of quality fish feed remains until today very attractive.

Unlike conventional wastewater treatment systems in more developed countries, where treatment quality is enforced by regulatory agencies, the revenue generation of Agriquatics provided sufficient incentive for the highest quality of treatment found in Bangladesh.

Value chain and position

The Agriquatics initiative was developed under the Kumudini Welfare Trust-PRISM Bangladesh partnership. These two partners provided the business with its most critical resources (wastewater, treatment ponds, technology and expertise). Having these in place, the business was positioned to buy its other inputs such as fingerlings and seeds from up-chain suppliers and sell its products (fish and crops) directly to end-users (local fish consumers; Figure 222).

FIGURE 221. BUSINESS MODEL CANVAS FROM THE PERSPECTIVE OF PRISM BANGLADESH (AGRIQUATICS)

KEY PARTNERS
- Kumudini hospital complex (KHC)
- Kumudini Welfare Trust (KWT)
- PRISM HQ
- Local community

KEY ACTIVITIES
- Treatment of wastewater
- Growing and harvest of crops, duckweed, fish
- Fish and crops sales
- Technical advice

KEY RESOURCES
- Land use rights; ready ponds
- PRISM technical expertise
- Wastewater, duckweed
- Capital access
- Fingerlings

VALUE PROPOSITIONS
- High quality wastewater treatment paid through the production of fish feed, crops and fish at competitive market prices, making the system free of fees or tariffs

CUSTOMER RELATIONSHIPS
- Recurrent purchase based on customer satisfaction (low price and availability)
- Contractual relation
- Strong (non-financial) public support

CHANNELS
- Direct selling on-site
- Contracts and direct interaction of partners at hospital site

CUSTOMER SEGMENTS
- Fish buyers (incl. Kumudini hospital complex)
- Crop buyers
- KWT (demanding wastewater treatment)

COST STRUCTURE
- Capital investment (loan and land lease)
- Regular fingerlings purchase/breeding costs
- O&M (mostly labor employed for duckweed farming, fish feeding, harvest and sale; and crop irrigation, harvest, sale); debt repay

REVENUE STREAMS
- Sales of fish
- Sales of crops

SOCIAL & ENVIRONMENTAL COSTS
- Laborers' health risk due to contact with wastewater
- Possible human health hazard from consumption of fish if contaminants are transported via duckweed to the fish and not destroyed by fish cooking

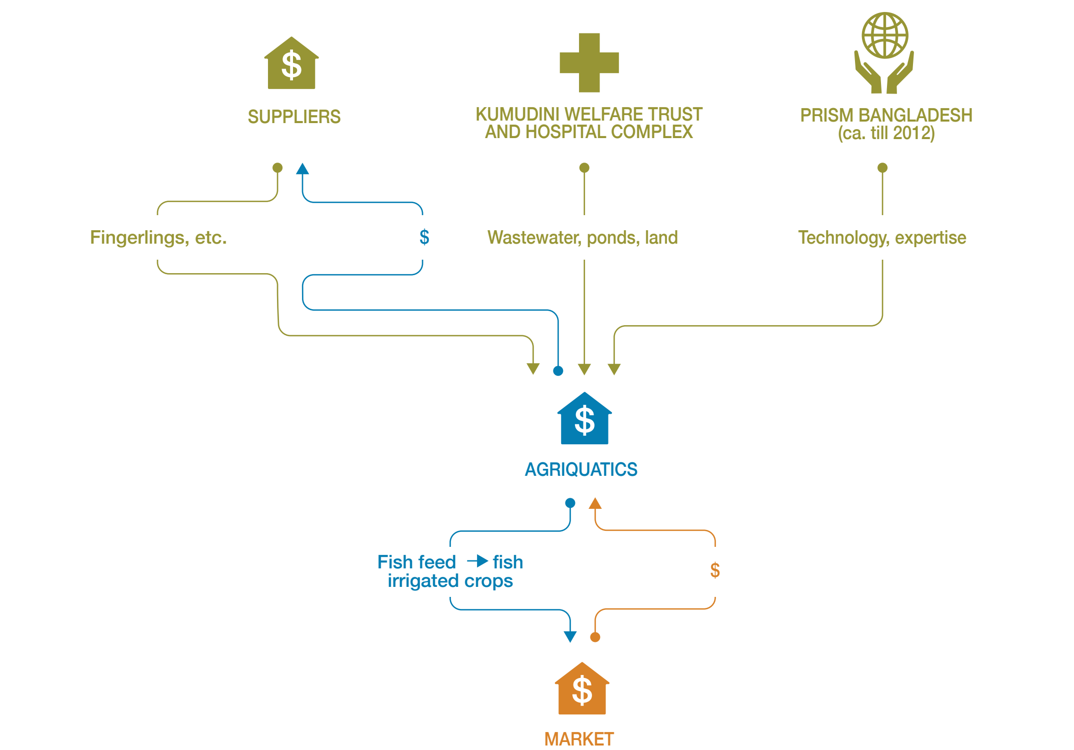
SOCIAL & ENVIRONMENTAL BENEFITS
- Wastewater efflux from hospital is treated, which results in reduced environmental pollution
- Support of jobs and protein supply for the local community
- Cheap food supply to the hospital supporting its free service to the poor

A notable portion of the fish and crops produced was bought by the hospital complex. Additional profits from water sales were not realistic in the local context as there is no market for the treated water due to the availability of adequate fresh water for agriculture, even in the dry season.

Institutional environment

The Kumudini Welfare Trust is a not-for-profit family trust managed by an external board of directors – one member of which is nominated by the Government of Bangladesh. PRISM Bangladesh is a not-for-

FIGURE 222. VALUE CHAIN OF THE BUSINESS MODEL



profit Bangladeshi NGO. The relationship between the two entities was specified under a succession of mutual agreements. At a later stage, PRISM's involvement phased out, while the treatment system continued to operate until 2013 when the Indian Government financed a new treatment plant for the hospital complex which was inaugurated on 7 June, 2015.

The wastewater fed aquaculture system received significant scientific interest. Public support was also strong, but involved no direct financial transaction beyond a continuing willingness by the local public to purchase fish. Agriquatics provided in-house training to the locals working as laborers. Linking between the sanitation and agricultural sector, the project fell under different policies and strategies without any direct support (see section on the Macro-economic environment above).

Technology and processes

The project inherited a defunct four-cell, single hectare facultative ponds complex and added to it a 0.6-ha plug flow duckweed wastewater treatment system. Only the first of the four ponds remains connected to the wastewater treatment system serving as a primary wastewater receiving and settling tank (Figure 223). The other three ponds were converted to fish production tanks, fed by groundwater and by the final effluent of the plug-flow (Iqbal, 1999).

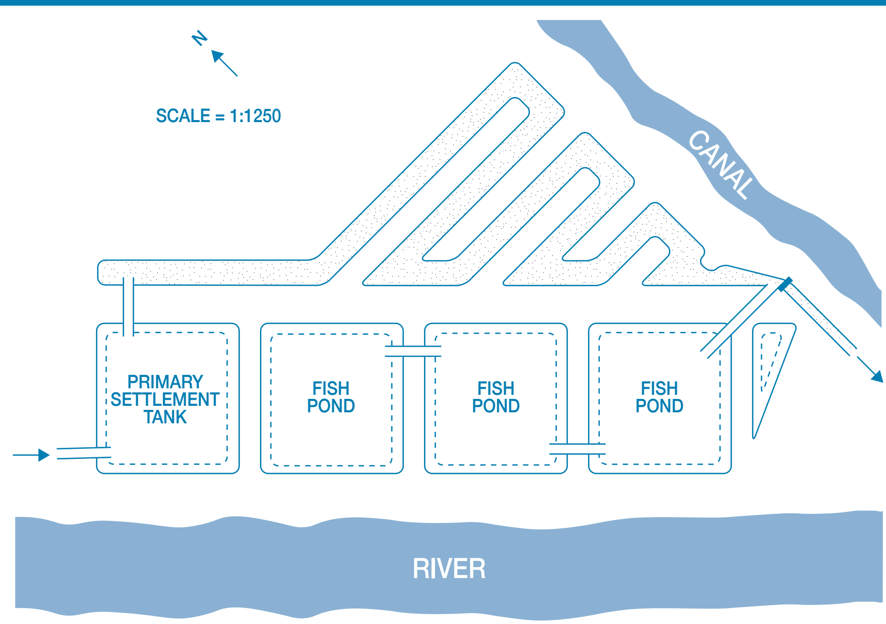
Except for an initial lift pump, the wastewater moves by gravity to and through the whole treatment system from the initial 0.25-ha pond with a hydraulic retention time of two to four days, and followed by the duckweed-covered, 0.6 ha plug flow lagoon constructed as a 500m long non-aerated

serpentine channel with seven bends. For this, depth of the lagoon increases gradually from 0.4 to 0.9m. The system was fed with a mixture of hospital, school and domestic (staff residencies) wastewater from a population of about 3,000–4,000 people with per capita production of wastewater estimated at around 100L/day. The hydraulic retention time in the plug flow wastewater-fed duckweed lagoon was estimated by different authors as 15–22 days, with parts of the water in the zig-zag been lost as seepage to the nearby canal. The lagoon was covered by a floating bamboo grid to contain the standing (100% cover) duckweed mat, at least in the first part of the system which is naturally the richest in nutrients. Early data suggest that the system produced 220–400t fresh duckweed/ha/year (about 17 to 31t dry weight/ha/year) (UNEP, 2002). Duckweed was harvested manually with nets, drained in bamboo baskets, weighed and then placed in one of 12 floating feeding stations distributed evenly across the surface of the originally three 0.25 ha fish tanks. Fish were fed in addition with rice bran and oil cake (Edwards, 2005).

Part of the treated water was eventually used to top up the fish tanks. Analysis by the International Center for Diarrheal Disease Research, Dhaka, Bangladesh, verified that indicator pathogen transmission to fish or workers was similar to control groups and within safety margins (Gijzen and Ikramullah, 1999; Islam et al., 2004). This might however not apply to all possible pathogens and heavy metals (see below).

The fish tanks were stocked with around 10,000 to 14,000 fingerlings at the onset of the monsoon season. The polyculture includes Indian major carp (Mrigal 25%, Catla 20%, Rohu 15%) and Chinese carps (Silver Carp 10%, Mirror Carp 20%, Grass Carp 10%). Tilapia was not stocked but fingerlings entered the tanks incidentally (UNEP, 2002). Fish were usually harvested twice a week. The production numbers varied between reports from on average of 7.5 to max. 15t/ha/year (of which usually a share got stolen).

FIGURE 223. LAYOUT OF THE WASTEWATER TREATMENT SYSTEMS AND FISH FARMING AT AGRIQUATICS



Source: After Iqbal, 1999.

Movement of wind across the surface was mitigated by strategic placement of crops such as bananas, taro, papaya and lentils along the perimeter. These also contributed to the income of the system.

Funding and financial outlook

Agriquatics had the advantage that wastewater collection and channeling were already in place and so the defunct pond system was redesigned for fish production. The land was leased on favorable terms, and capital investments for the labor intensive construction of the plug flow system were limited. Financial support was provided by United Nations Capital Development Fund (UNCDF).

In view of operational cost recovery, a portion of the fish produced was bought by the hospital which provided financial security. Both initial partners (KWT and PRISM) had obvious interests in the effective operation of the system: KWT to achieve the effective treatment and proper disposal of its wastewater; PRISM to promote the duckweed technology while generating financial returns. Based on audited records from the first eight years (Table 52), revenues allowed a pay back of the initial loan from PRISM in about six years. Since then the wastewater-fed duckweed-fish system generated an annual net profit of about USD 2,000–3,000, which is larger per hectare than e.g. that of rice, the major agricultural crop in the area. The internal rate of return was calculated as about 25.9% (Gijzen and Ikramullah, 1999; UNEP, 2002; Patwary, 2013).

TABLE 52. AVERAGE ANNUAL INCOME AND EXPENDITURES 1993–2000 IN TAKA (USD 1 = 40–50 TAKA IN THIS PERIOD)

DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	8 YEARS AVERAGE
1. Recurring operational Cost									
Land rental (2 ha)	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000	26,000
Staff salary and wages	85,600	92,020	98,922	106,341	114,317	122,891	129,036	136,480	110,701
Field supplies (duckweed)	10,000	12,000	13,500	14,300	15,200	15,960	15,678	16,512	14,144
Field supplies for agriculture & fish	28,000	29,000	30,000	31,000	33,000	32,300	34,000	33,600	31,363
Energy/fuel cost (pump)	43,500	45,500	47,900	50,430	55,720	58,500	62,400	63,100	53,381
Maintenance	13,700	14,000	14,500	15,200	16,720	17,556	18,375	18,500	16,069
Miscellaneous	6,285	6,580	7,000	7,350	7,700	7,900	7,500	7,720	7,254
Subtotal annual operation cost	**213,085**	**225,100**	**237,822**	**250,621**	**268,657**	**281,107**	**292,989**	**301,912**	**258,912**
Depreciation of loan (10 years)	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
Management overhead (7.5%)	15,981	16,833	17,837	18,797	20,149	21,083	21,974	22,643	19,412
Financial costs (9.5% on work capital)	10,450	10,925	11,590	12,350	13,300	13,352	13,916	14,340	12,528
Subtotal admin & finance costs	**51,431**	**52,758**	**54,427**	**56,147**	**58,449**	**59,435**	**60,890**	**61,983**	**56,940**

DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	8 YEARS AVERAGE
Total annual recurring costs	**264,516**	**277,858**	**292,249**	**306,768**	**327,106**	**340,542**	**353,879**	**363,895**	**315,852**
2. Income from farm revenue									
Sale proceed from duckweed-fed fish	128,778	253,800	316,509	402,231	404,982	445,702	419,440	413,354	348,100
Sale proceed from agriculture & fruits	25,000	30,000	34,000	44,000	65,000	58,250	56,667	60,223	46,643
Miscellaneous sales	3,600	4,400	4,600	5,200	5,400	5,200	5,100	5,600	4,888
Total income from sales	**157,378**	**288,200**	**355,109**	**451,431**	**475,382**	**509,152**	**481,207**	**479,177**	**399,631**
3. Operational profit	**-55,707**	**63,100**	**117,287**	**200,810**	**206,725**	**228,045**	**188,218**	**177,265**	**140,719**
4. Net profit before taxes*	**-107,138**	**10,342**	**62,860**	**144,663**	**148,276**	**168,610**	**127,328**	**115,282**	**83,779**

* No tax on agro-production (tax holiday)
Source: Patwary, 2013; modified.

Socio-economic, health and environmental impact

Local studies showed that duckweed recovered a significant portion of the nutrient value inherent in the wastewater, so much that in the last part of the zig-zag system it hardly grew due to low nutrient content. The nutrient removal had a positive impact on the effluent receiving water body and its water quality, reducing potentially human health-related costs in the vicinity. But nitrogen as ammonium and nitrate was not only efficiently captured through phytoremediation, but also transformed into protein rich biomass. Based on water quality data (oxygen demand, nitrogen, phosphorus) by Alaerts et al. (1996) and fecal coliform analysis by Islam et al. (2004), treated wastewater discharged to the adjacent river could be considered among the highest quality of treated wastewater in the country attainable without use of reverse osmosis and fit for unrestricted irrigation of vegetables according to WHO standards for wastewater reuse (UNEP, 2002). Further disinfection of the treated effluent prior to its discharge into the river had been considered, but found to be prohibitive on the basis of cost.

While the harvest of duckweed significantly exposed workers to wastewater and its pathogens, scientific monitoring could not determine a cause-effect relationship between incidences of worker diarrheal disease infection and their working at the site (Gijzen and Ikramullah, 1999). Also fish was tested to be safe for consumption. However, while duckweed absorbs nutrients, it also absorbs heavy metals, and if it used as herbivorous fish feed, the metals can be bio-accumulated as it was locally verified (Parven et al., 2009). There can also be gastroenteritis-causing bacteria which persist in the treatment system and might spread to fish (Rahman et al., 2007). An impact from such a pathogen transfer on human consumers was however considered low as fish is generally not eaten raw in Bangladesh (Gijzen and Ikramullah, 1999). Data on other potential contaminants such as estrogen or pharmaceutical residues do not exist. The recommendation was made that related research be included also in any replication of the system.

Entry into aquaculture appears to have fewer gender barriers, as this sector developed outside cultural traditions. According to FAO, Bangladeshi women make up about 60% of fish farmers, and many are successful entrepreneurs[3]. And while women's involvement in aquaculture has importantly improved the economic, nutritional and social benefits for their family, their work goes largely unrecognized in official statistics.

Scalability and replicability considerations

Over its lifetime, the Agriquatics system recovered several times its investment costs, which is unique in the domain of wastewater treatment. The key drivers for the success of the business were:

- Availability of land.
- Limited capital cost with several profitable revenue streams for high-value products resulting in fast payback.
- Low-tech and -cost treatment system supported by a mutually beneficial partnership ensuring availability of water, expertise and system maintenance.
- Profit incentive for treatment of wastewater that obviates requirement for external supervision and controls.

It is important to note that the positive financial performance of the wastewater treatment and aquaculture system was a product of a mutually beneficial partnership which created favourable conditions, such as no major costs for wastewater collection and channelling, and favourable terms for capital investment, land lease and cost recovery.

A pillar of the success was the value creation in terms of fish, i.e. to capitalize on increasing revenues with moving up the value chain, compared to treatment plants only providing treated water. On the other hand, the requirement for a suitably large land area for the combined treatment – aquaculture system will be a common constraint within towns and cities. This is especially true for Bangladesh with its very high population density, land speculations and rising opportunity cost of land, in particular within urbanizing areas (Edwards, 2005). An opportunity in drier areas could be to link such systems with inner-urban or peri-urban green belts, as realized in Parque Huascar in Lima, which can create significant social value[4], or biodiversity reserves. From a health perspective, it has to be added that although the system in Mirzapur was set up at a hospital, its replication potential will be highest where the wastewater derives only from domestic settings with minimal risk of chemical contamination.

Aside its benefits of nutrient accumulation and high crude protein production, also duckweed has some biological constraints which can limit its use in other regions: its growth is adversely affected by both low and high temperatures, and high light intensity; occasional insect infestation; and rapid decomposition following harvest, i.e. the fish ponds have to be in proximity.

Summary assessment – SWOT analysis

The success story builds on a win-win situation of treatment quality and revenue generation combined with favourable low capital and O&M costs, and a high-value product allowing the recovery of both operational and investment costs. The system requires a relatively large land investment for the spatial combination of aquaculture and treatment systems. Figure 224 shows the SWOT analysis of this business case.

FIGURE 224. SWOT ANALYSIS OF AGRIQUATICS BUSINESS CASE

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Viable business model based on multiple revenue streams, cost recovery and net profit ▪ Limited capital and low O&M costs ▪ Green infrastructure image with positive environmental impacts ▪ Mutually beneficial partnership enabling free supply of wastewater and land including lagoons at favorable terms ▪ Expertise in duckweed-fed fish farming	**WEAKNESSES** ▪ Significant land-size requirement ▪ No direct governmental support ▪ Monitoring of system safety remained fragmentary ▪ Sensitive to flooding ▪ Fish farming not possible with increasing chemically contaminated wastewater
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Rising fish demand ▪ Increasing demand for green infrastructure ▪ Proof of concept for replication ▪ Short pay-back period ▪ Grey legal area	**THREATS** ▪ Possible industrial effluent ▪ Undetected human health risks ▪ Local aquaculture competition ▪ Changing government policy toward wastewater reuse in aquaculture ▪ Area wide flooding (happened twice)

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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2016. As business operations are dynamic data can be subject to change.

Notes

1 PRISM: Project in Agriculture, Rural Industry Science and Medicine. The PRISM group was founded in the 1980s as an international non-profit organization focusing on the support of local and family enterprise within rural communities in developing countries. PRISM Bangladesh was created as an affiliate of the PRISM Group in 1990 (Torres 1993).

2 Lemnaceae ("duckweed"), a family of aquatic macrophytes converts nutrients from the wastewater into protein rich biomass, that can be used as poultry and fish feed. According to Leng (1999), on average 40–50 tons of dry matter can be produced per year per hectare under optimal conditions, allowing the production of more protein per ha and year than via soybean or groundnut (Patway, 2013).

3 www.fao.org/gender/gender-home/gender-programme/gender-fisheries/en/ (accessed 5 Nov. 2017).

4 https://wle.cgiar.org/thrive/2013/09/02/wastewater-reuse-benefits-beyond-food-production (accessed 5 Nov. 2017).

CASE

A public-private partnership linking wastewater treatment and aquaculture (Ghana)

Philip Amoah, Ashley Muspratt, Pay Drechsel and Miriam Otoo

Supporting case for Business Model 18	
Location:	Kumasi, Ghana
Waste input type:	Municipal wastewater
Value offer:	African catfish, treated water
Organization type:	Public-private partnership (PPP)
Status of organization:	Operational 2010–2012 (later transformed into a research project)
Scale of businesses:	Small-medium
Major partners:	Waste Enterprisers Ltd. (now: Waste Enterprisers Holding) Kumasi Metropolitan Assembly (KMA), Ghana Kwame Nkrumah University of Science and Technology (KNUST), Department of Fisheries and Watershed Management, Kumasi International Water Management Institute (IWMI), Accra

Executive summary

In Kumasi, Ghana, a public-private partnership was established between the Kumasi Metropolitan Assembly (KMA) and the private company Waste Enterprisers Ltd. (WE) to use aquaculture as a source of revenue for sustaining the sanitation services. As part of the agreement, WE is allowed to stock catfish in the final maturation pond(s) of governmental owned wastewater treatment plants, while in return WE uses half of its fish-sale profit to facilitate regular plant maintenance. This arrangement helps WE to access water and infrastructure for fish farming without related capital expenditures, while KMA gets its treatment plants well maintained which was so far more than challenging.

The business was co-funded by both parties without external support. Further beneficiaries are the low-income households charged for maintenance of the Waste Stabilization Ponds (WSP) and the maintenance subcontractor who is entitled of collecting the household fees.

Selling smoked catfish which is in high demand can make already the management of one treatment plant viable. For (unsmoked) fresh fish, with optimized production, break-even can be achieved from two managed plants upwards although only from three systems up the economic indicators

will be positive. With full compliance with safety regulations and policy support, the model is easily transferable to other locations, as pond based treatment systems are very common in the tropics.

The case is an example of an innovative pro-poor PPP that helps to ensure the sustainability of a wastewater facility whilst providing benefits to the community. During its engagement in Kumasi, WE rehabilitated two WSP, built rearing infrastructure for its fingerlings, and increased stock survival rates from less than 10% to 80% over the course of four cultivations. This case attracted international donor funding for accompanying research.

KEY PERFORMANCE INDICATORS (AS OF 2012)						
Land use:	230–266m^2 (per fish pond); about 1 ha (total WSP)					
Water use:	225m^3/day					
Capital investments:	Limited to fish hedging as ponds were in place. From a PPP perspective, less than 30% borne by WE and over 70% by KMA					
Labor	2 staff (part-time), 2 workers					
O&M costs	USD 3,429 /year/WSP (for 5 WSP systems), to USD 11,440 /year/WSP (for 1 WSP)					
Output:	Per hectare (water): 40 tons/year of fish; Per actual area: 2 tons/year from two ponds					
Potential social and/or environmental impact:	Reduction in public sanitation and health expenditures, improvement in food supply and job creation; poor households exempted from treatment plant maintenance fees					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR:	45%	Gross margin:	N.A.

Context and background

Kumasi is the capital of Ghana's Ashanti region and the second largest city in the country with a 2013 population of over 2 million and an annual growth rate of about 4–4.5%. The increasing population is challenging urban water and sanitation services. Like across Ghana, also the wastewater treatment facilities in the Kumasi metropolis are not or only partially functioning due to constrained institutional and financial resources (Murray and Drechsel, 2011). The resulting pollution of water bodies remains unchallenged as the enforcement of environmental regulations is especially weak for governmental infrastructure. Innovative partnerships and financing mechanisms are needed for sustainable wastewater management.

Waste Enterprisers (WE) is a non-profit organization, which focuses on building business models that incentivize waste collection and treatment services without further burden for poor households (tariff-independency). WE was set up with the goal to create demand for value-added waste products whilst providing an avenue for investing a portion of profits back into the sanitation sector, generating cycles of local investment, sustainable sanitation and healthier communities (Murray and Buckley, 2010).

In early 2010, WE approached KMA with its PPP proposal. The business locations of WE in Kumasi were the Ahinsan and Chirapatre housing estates and their wastewater treatment systems. Both were built in the late 1970s by the now-defunct State Housing Corporation of Ghana. Over 200 houses in each community (with ca. 1,500 inhabitants in Ahinsan and ca. 1,800 in Chirapatre) are connected to a communal sewerage network, which, along with storm-water runoff, is channelled to the respective WSP for treatment (Tenkorang et al., 2012). Like most sanitation facilities in Ghana, both WSP systems have chronically lacked reliable maintenance. In theory, a KMA subcontractor is responsible for raising the necessary fees from the served households for undertaking the maintenance of the plant. However, as households are poor and consider this a task of the municipality, the effort of collecting the fees erases any incentive to do the job and ponds were hardly maintained over years (Tenkorang et al., 2012).

The aquaculture production by WE was accompanied by an extensive testing of fish quality and safety. Studies targeted pathogenic contamination, heavy metals and pharmaceutical residues (Amoah and Yeboah-Agyepong, 2015a; Asem-Hiablie et al., 2013). Also the cultivated species, African Catfish (*Clarias gariepinus*), was chosen for safety reasons as in the study region it is normally smoked and not consumed fresh, but cooked.

Market environment

Traditionally, fish is the preferred and cheapest source of animal protein in Ghana with about 75% of total annual production being consumed locally. Tilapia constitutes about 80% of aquaculture production, while catfish accounts for the remaining 20%. According to Cobbina and Eiriksdottir (2010), fish trading is an important occupation in Ghana with an estimated 10% of the population engaged in it, on a full time or part time basis, both in rural and urban communities. Commercial farms mostly deal with wholesale buyers who buy the bulk of the harvested product and go on to sell to retailers or fish processors while fish harvested by the non-commercial farmers is mostly retailed by themselves or their spouses. Only a few non-commercial farmers sell their product to wholesale buyers. Unsold fish is either frozen or processed via smoking, salting and/or fermentation. Fish availability and marketing is most common in the southern and the middle zone of Ghana (GLSS, 2014). Ghana's Ashanti region is currently the leading region in pond-based fish farming in Ghana, with about 1,205 fish ponds, involving over 500 fish farmers. Available water surface area in Ashanti for fisheries development is about 151 ha producing about 585 metric tons of fish annually. Ashanti also leads in the production, supply and export of catfish in Ghana (Rurangwa et al., 2015).

In Kumasi, the majority of people consume catfish at home and in street restaurants which offer traditional stews. About 68% of the interviewees indicated to eat fish eight times per month or all three to four days (Amoah et al. 2015b). The 2014 Ghana Living Standard Survey recorded an annual food budget share of 15.8% for fish and seafood, which is nationwide the second most important food consumption subgroup, after cereals (e.g. rice and bread) (17.7%), and twice as high as meat (GLSS, 2014). Product attributes that influence consumers' decisions prior to purchasing fish are price, size and quality of the fish. Source of fish is among the least important product attributes influencing consumers' decision. In surveys which explained the wastewater use, consumers in Kumasi reconfirmed that they are more likely to choose fish farmed in treated wastewater if it was less expensive and larger than fish from other sources (Amoah and Yeboah-Agyepong, 2015b), which mirrors consumers' behaviour in view of wastewater irrigated vegetables (Keraita and Drechsel, 2015). An indicator of demand and tolerance of the source of water is the frequent theft of fish directly from the wastewater treatment ponds.

Macro-economic environment

Ghana's total annual fish requirement has been estimated to be 880,000 t while the nation's annual fish production average is 420,000 t, leaving a significant deficit. This deficit is partly made up for through fish imports which were estimated at 213,000 t in the year 2007 and valued at USD 262 million (Cobbina and Eiriksdottir, 2010). However, import of farmed fish is not allowed so as to ensure good prices for local fish farmers. However, illegal import, especially of Tilapia, is a growing concern. The deficit between fish demand and production has been a main driving force for pushing the agenda of developing aquaculture (Awity, 2005). Studies conducted by Asmah (2008) reported a 16% mean annual growth rate in the number of aquaculture farms since the year 2000. Fish production in ponds range from about 35 kg to over 35t/ha/year (Asmah, 2008), with less than 10% of commercial farmers exceeding production levels of 20t/ha/year. Common production cycles range between seven and 12 months (Asmah, 2008).

Business model

The partnership arrangement between the WE and KMA offers an interlinked double value proposition: maintaining the treatment capacity financed through waste valorization via fish production (Figure 225). The model ensures that WE gets nutrient rich water at no cost and KMA derives benefits from cost savings, as a more reliable WSP maintenance will lead to lower public health expenditures

FIGURE 225. BUSINESS MODEL CANVAS – FROM THE WE PERSPECTIVE

KEY PARTNERS

- Kumasi Metropolitan Assembly (KMA)
- Kwame Nkrumah University of Science and Technology (KNUST)
- International Water Management Institute (IWMI)
- Fingerling and feed supplier

KEY ACTIVITIES

- Maintain wastewater treatment functions
- Production of fingerlings and fish
- Fish marketing, sale and trust building
- Research and development

KEY RESOURCES

- Wastewater, land, treatment ponds
- Labor, capital
- Fingerlings, extra feed
- Expertise, laboratory access

VALUE PROPOSITIONS

- Improved wastewater treatment at no cost for the authority through resource recovery for fish (protein) farming

CUSTOMER RELATIONSHIPS

- Personal contact with wholesalers of harvest times
- Personal (on-site) contact with WSP maintenance sub-contractor

CHANNELS

- Direct sales to wholesalers
- Direct contracting of maintenance staff (if not done by KMA)

CUSTOMER SEGMENTS

- Wholesalers/ fish smokers
- Maintenance sub-contractor

COST STRUCTURE

- Capital investment (max. 30 %)
- Regular fingerling purchase
- Pond O&M (sub-contracted)
- Fish harvest, marketing, sales
- Fish farming research and development cost
- Debt repay

REVENUE STREAMS

- Fish sale

SOCIAL & ENVIRONMENTAL COSTS

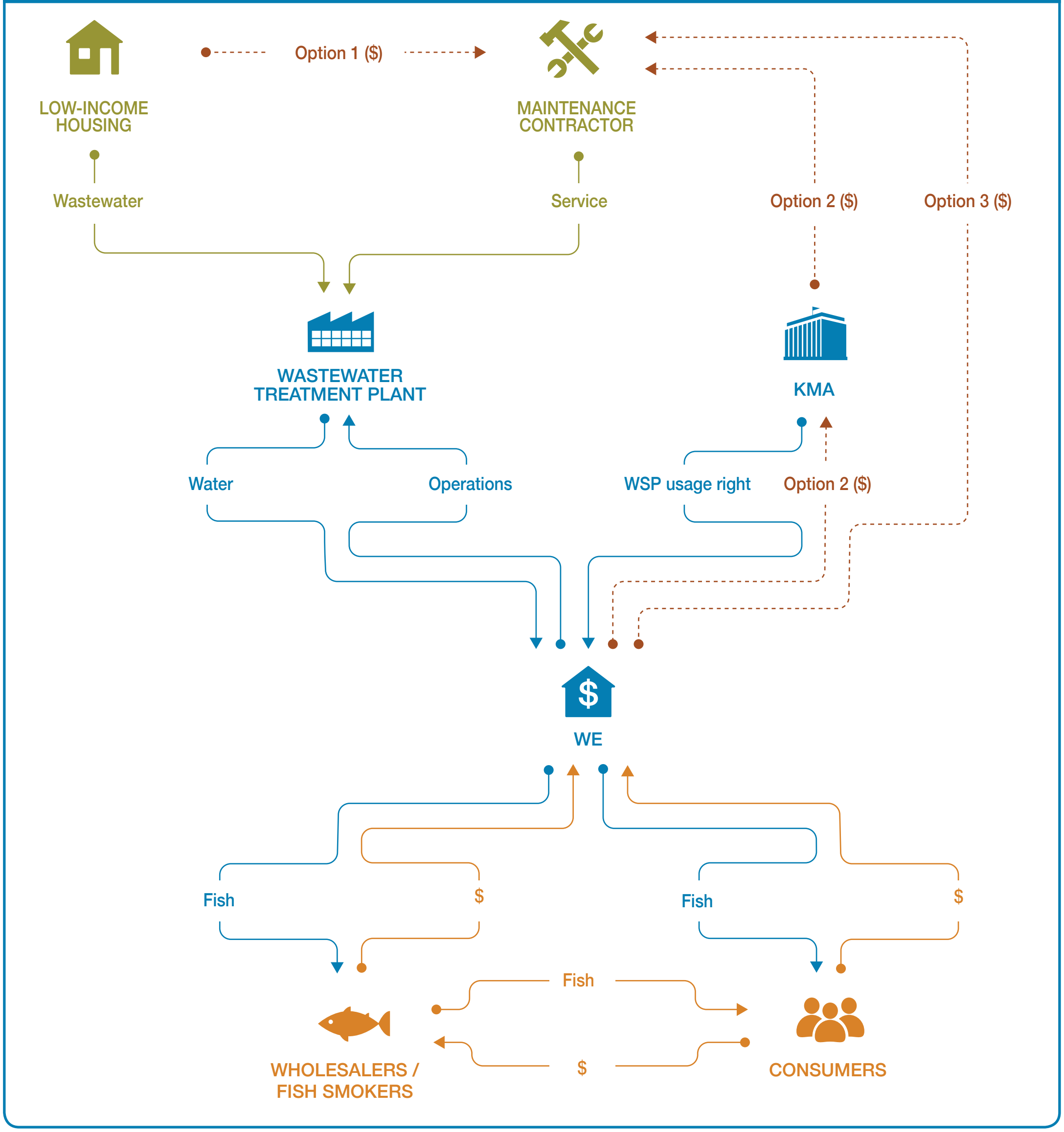
- Potential health risks of plant workers and through fish consumption if monitoring and the HACCP system fail
- Potential risk to biodiversity if fish escapes

SOCIAL & ENVIRONMENTAL BENEFITS

- Improved wastewater treatment and public health
- Reduced food miles and increased protein supply
- Poor households exempted from maintenance fees

from insufficiently treated wastewater entering the environment. Other beneficiaries are (i) the WSP-connected households which were so far asked to pay the maintenance contractor (see Figure 226, option 1); and (ii) the contractor who faced significant opportunity costs trying to collect the household fees. While KMA provides the land and pond system, WE cultivates the fish under strict safety monitoring standards. KMA as public partner is not paying the WE for the expected service; in contrary, any profit WE achieves is shared 1:1 with the public utility allowing it to improve sanitation services, like to fully pay for pond maintenance (see Figure 226, option 1)[1], i.e. without need for the subcontractor to collect fees from the served households which appeared difficult as both estates were set up for low-income groups.

FIGURE 226. BUSINESS PROCESS FLOW OF WASTE ENTERPRISERS



So far, WE and its operational 'successors'[2] sold the produced catfish very easily to wholesalers who smoke the fish or sell it to fish smokers. Wholesalers are typically contacted and notified of harvest times. WE sold initially their product at a competitive price (USD 3/kg) equivalent to local market prices but could achieve far higher revenue by smoking its fish before sale, which would also help to control pathogenic health risks. One of the key strengths of the aquaculture business model is that once the WSP is in place, the additional start-up costs are low, and the operating costs (in particular staff salaries) become bearable with more than two WSP to manage. However, the fish production needs a pre-run to optimize fish stocking, feeding and survival (Amoah and Yeboah-Agyepong, 2015b). The key elements of the business model canvas are presented above.

Value chain and position

The fish produce is up to 80% directly supplied to wholesale/fish smokers, while 20% goes to consumers who roast or smoke the fish before it gets cooked (Figure 226). Up till now, demand for catfish remains higher than supply, and all fish brought offered gets also sold. Parts of the revenues from fish sale are used to maintain the treatment quality of the WSPs, without charging the low-income neighborhood. Although the "source of fish" is so far among the least important product attributes influencing consumers' purchasing decisions, a potential threat to the viability of the business could be that despite safety controls, traders or consumers start rejecting the fish.

Institutional environment

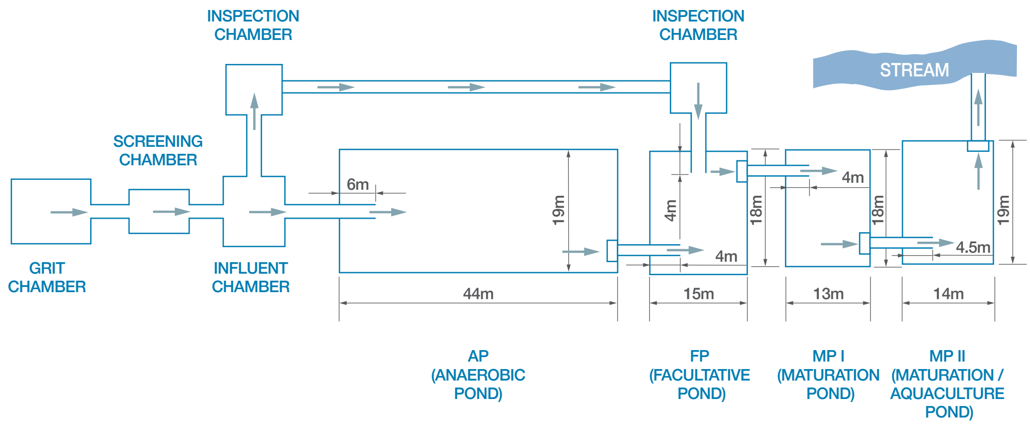
This is a public-private partnership business between WE and the city of Kumasi (KMA), where WE controls the operation and management of the WSP and KMA supplies the land with its treatment infrastructure and wastewater. While there are no legislations in Ghana that explicitly promote or ban the use of wastewater for aquaculture, an environmental impact assessment is required for commercial aquaculture[3]. With the permit from the Ghana Environmental Protection Agency (EPA) and a permit for (fresh) water usage from the Water Resources Commission (Act 522, 1996) the Fisheries Commission will approve the business. The WE-KMA public private partnership did not fit into the common scheme and was authorized through the agreement of the city to enter into contract with WE to support environmental sanitation in the city. Since then, the National Aquaculture Development Plan of 2012 was developed, which calls among others for more attention to fish health, and the 2013 established Ministry of Fisheries and Aquaculture Development published in 2014 through the Fisheries Commission, "National Aquaculture Guidelines and Code of Practice" to set minimum standards for operators in the aquaculture value chain and also prevent any possible negative impact of aquaculture on the environment in line with the Fisheries Regulations 2010 (L.I. 1968) and Fisheries Act, 2002 (Act 625).

WE's business was from 2011-on accompanied by research, e.g. on feeding, stocking and food safety by the Department of Fisheries and Watershed Management, Kwame Nkrumah University of Science and Technology (KNUST) and the International Water Management institute (IWMI). This was supported by a grant from the African Water Facility to Ghana's Water Resources Commission.

Technology and processes

In both project locations, the WSPs were overgrown and dysfunctional when WE arrived. The setup of the WSP systems is shown in Figure 227 on the example of Ahinsan. The system is made up of five sludge chambers: a grit, screening, influent, two inspection chambers and four treatment ponds, which were overgrown before WE took the WSP over. The four treatment ponds are: anaerobic pond (AP), facultative pond (FP), and first and second maturation ponds (MP I, MP II). Given the fixed number of connected households, the series of ponds make up an effective and low-cost means of treating wastewater, if well maintained. The last pond (MP II) or depending on water quality also MP I

FIGURE 227. TREATMENT PROCESSES OF THE WSP SYSTEM AT AHINSAN, KUMASI, GHANA



and MP II are used to cultivate catfish, which has a relatively high tolerance for low levels of dissolved oxygen. Phosphorus and nitrogen provided with the wastewater are essential to facilitate production of natural microscopic plants and plankton which are food for the fish. There are two growing seasons per year and three fingerlings per m^2 are stocked in both maturation ponds per season, targeting an average annual production of about one ton per pond or 2t of fish per treatment plant with a survival rate of about 80%[4]. WE holds no inventory of fish at harvest and sells its product easily to wholesalers to be resold in the local markets to consumers and fish smokers for processing. Wholesalers are typically contacted and notified of harvest times.

Funding and financial outlook

Aquaculture, in general, appears to be a good business option in Ghana. A feasibility study by the Ministry of Food and Agriculture (MoFA) for Tilapia, indicated a positive Net Present Value (NPV) and Internal Rate of Return (IRR) of 32%, a Benefit Cost Ratio (BCR) of 1.18, and a payback period which is slightly longer than four years (Cobbina and Eiriksdottir, 2010). Aside labor and management costs, the cost of feed forms the bulk of the variable cost. Sensitivity analysis showed that the cost of feed, the fish survival rate as well as the farm gate price of fish are the main factors affecting profitability, while the most constraining factor for commercial aquaculture are the high start-up cost of which about 68% are fixed costs.

In the presented business case of WE, the possibility to use existing infrastructure, provided a huge cost saving (covering nearly all fixed cost except rearing infrastructure for fingerlings). Although wastewater was expected to support the development of a significant amount of feed for the fish, the experience of WE showed that this is not sufficient (or sufficiently balanced) and feeding remains recommended. This feeding pays off as catfish grown with wastewater eventually grew much larger than fish in freshwater control ponds (Amoah and Yeboah-Agyepong, 2015b).

Table 53 presents financial projection based on WE data for the management of one to five WSP systems, using a ten-year planning horizon. Data show that although with two systems, the business can break even, with three or more WSPs, staff costs are most efficiently used, resulting in a viable business with NPV and IRR positive.

TABLE 53. INCOME STATEMENT OF WASTE ENTERPRISES

NUMBER OF WSP SYSTEMS				1	2	3	4	5
COST ITEMS								
A) Capital investment			GHC	4,495	8,990	13,485	17,980	22,475
B) Production Costs								
	Cost/ stocking	Stocking/ year						
Fingerlings	225	2	GHC	450	900	1,350	1,800	2,250
Fish Feed	70	2	GHC	140	280	420	560	700
Pond/Tank Maintenance	Cost/ stocking	Stocking/ year						
Patching Cement	10	2	GHC	20	40	60	80	100
Chlorine	10	2	GHC	20	40	60	80	100
Pond Liming	120	2	GHC	240	480	720	960	1,200
Hand Sanitizer	25	2	GHC	50	100	150	200	250
Total production costs			GHC	920	1,840	2,760	3,680	4,600
C) Administrative Costs								
Employees	Annual Salary							
Manager	GHC	15,000	GHC	15,000	15,000	15,000	15,000	15,000
Grounds Keeper	GHC	1,200	GHC	1,200	2,400	3,600	4,800	6,000
National Health Plan	GHC	20	GHC	40	60	80	100	120
Total Administration Costs			GHC	16,240	17,460	18,680	19,900	21,120
D) Total Operating Costs			GHC	17,160	19,300	21,440	23,580	25,720
Operating cost/system			GHC	17,160	9,650	7,147	5,895	5,144
REVENUE ITEMS								
E) Total revenue per number of systems			GHC	9,720	19,440	29,160	38,880	48,600
Administrative Cost as percentage of Total Revenues				167.0%	89.8%	64.0%	51.1%	43.4%

Production cost as percentage of Total Revenues		9.5%	9.5%	9.5%	9.5%	9.5%
Total Cost as percentage of Total Revenues		176.5%	99.3%	73.5%	60.6%	52.9%
PROFIT ITEMS						
F) Total Profits	GHC	(7,440)	140	7,720	15,300	22,880
Interest Income/ (Expense)	GHC	–	–	–	–	–
Taxes	GHC	–	–	–	–	–
Total profits before Interest & Taxes	GHC	(7,440)	140	7,720	15,300	22,880
G) Net Profits	GHC	(7,440)	140	7,720	15,300	22,880
Net profits as percentage of Total Revenues		–76.5%	0.7%	26.5%	39.4%	47.1%
Net Present Value (calculated over a 10-year period)	GHC	(36,516)	(5,118)	25,030	55,178	85,325
Internal Rate of Return (calculated over a 10-year period)	negative net cash flows over 10 years		–17%	82.0%	119%	141%
Break-even year (calculated over a 10-year period)	not in ten years		year 1	year 1	year 1	year 1

Source: Waste Enterprises; updated.

1 Reported financials for Year 1 of business with two annual harvests of two 250m² ponds per system. 20% mortality rate. Fish sold fresh.
2 Aquaculture business has tax exemption for the first 5 years and thereafter an income tax of 10% is assumed. Capital costs after depreciation over 10 years.
3 Inflation rate assumed at 8% as in 2011/12; Exchange rate in mid-2011: USD 1.0 = GHC (GHS) 1.50.

Another option to make already a one-WSP system viable is to sell fish **smoked** and not fresh which allows a much higher sales price and return. For such a case, WE internal projections estimated for catfish an IRR of up to 45% (at 20% discount rate). With an estimated profitability index of 2.1, and a BCR of 1.13, a payback period of three years was estimated under favorable stocking and sales conditions (Amoah et al., 2015b).

As experience in wastewater aquaculture had first to be gained, time was lost with optimizing production on both WE sites, and after two years, revenues hardly covered daily operations. As indicated in the sensitivity analysis the profitability improved with increased fish survival, which was supported by the accompanying research. For the research, WE in association with IWMI and Ghana's Water Resources Commission attracted external funding from the African Water Facility. After its successful proof of concept, Waste Enterprisers planned initially to expand its aquaculture business across Africa with a Technical Director in charge of fish-farming, but then received funding to engage in another resource recovery challenge and discontinued fish farming (IWMI, 2012) while the accompanying research continued at the WSP sites until 2015.

Socio-economic, health and environmental impact

At the aggregate level, the business will help with the reduction in public health expenditures through avoided cost of diseases associated with untreated or only partially treated sewage entering surface water bodies, thereby leading to their improvements. On the other hand, health risks of workers at the WSPs, fish traders and consumers have to be assessed, monitored and minimized. This objective was supported through studies addressing pathogenic contamination, as well as the accumulation of heavy metals and pharmaceutical residues (Amoah and Yeboah-Agyepong, 2015a; Asem-Hiablie et al., 2013). Also the type of fish (African Catfish; *Clarias gariepinus*) was chosen for safety reason as in the study region it is normally smoked and cooked before consumption. As the Fisheries Act does not address fish health, quality assurance or product safety, a WHO recommended Hazard Analysis and Critical Control Point (HACCP) system was developed which allows to monitor a number of critical control points where compliance with safety procedures interventions is required to reduce or eliminate potential health risks (Yeboah-Agyepong et al. 2017).

In view of environmental impacts, the WSP rehabilitation and maintenance will improve the environmental situation. As wastewater aquaculture is so far not addressed in any legislation, the Ghana Environmental Protection Agency (EPA) became member of the steering committee of the business accompanying research.

Although fish meat analysis did so far not point at actual risks, in the Ahinsan or Chirapatre system, critical control-points are the smoking of the fish directly after harvest as well its well-cooked consumption to remove pathogens from fish surface. An additional safety option would be to purify the fish in a fresh water pond after harvest and prior to sale, i.e. to clean as far as possible also the fish's digestive tract. Smoking of fish on-site, would also increase its market value, i.e. sales price.

Scalability and replicability considerations

In general, the investment climate for aquaculture is across and beyond Africa very positive. To promote and encourage new aquaculture enterprises in Ghana, they are granted for example a five-year tax free period (Cobbina and Eiriksdottir, 2010).

The use of (treated) wastewater for fish farming is more challenging. It has a long tradition, especially in Asia, and although it is supported by WHO (2006) with an own set of guidelines, many authorities might not agree with the idea especially where risk monitoring is weak. On the other hand, pond-based treatment systems are very common in many tropical countries, supporting housing estates, towns, military camps, universities, boarding schools, etc. Moreover, the majority of these systems are on a similar trajectory to failure as observed in Kumasi (Murray and Drechsel, 2011). Thus, the general drivers for the success of the business are:

- Supportive (or at least non-restrictive) regulations and policies, and positive perceptions.
- High local demand for catfish, allowing to share profits.
- Win-win public-private partnership resulting in low capital cost investment by the private partner.
- Research partnership to monitor and optimize system safety and productivity.

The implemented model has a significant potential for replication and scaling up if compliance with national or international safety guidelines such as WHO (2006) can be assured. The accompanying research in Kumasi resulted in fish farming manual and implementation plan summarizing the lessons learnt from wastewater aquaculture (Amoah et al., 2015a; Amoah and Yeboah-Agyepong, 2015b). But even with full compliance, market demand remains also a function of risk awareness and consumer perceptions, which has to be considered in local feasibility studies. Where wastewater treatment systems are to be newly set up for aquaculture, land requirements for pond-based systems have to be considered. The maintenance of the ponds can eventually be outsourced, or become part of the business.

Summary assessment – SWOT analysis

The model WE developed was intended to inspire opportunities that exist for using the resource value of human waste to the economic benefit of the sanitation sector. The aquaculture business supports via the productive use of treated wastewater the maintenance of otherwise dysfunctional wastewater treatment plants without charging poor households. With fish being nation-wide the second most important food consumption subgroup, market demand, especially for catfish is high. The strength of the business (Figure 228) is its ability to negotiate for the supply of free wastewater and land, which helps reduce fixed cost by 70%. The benefits are equally important for the municipality which is lacking funds to maintain environmental and human health. The HACCP system, fish smoking and boiling minimizes risks, and make the fish acceptable to traders. However, changing public perception remains a potential threat. Day to day challenges were more of technical nature, like optimizing fish survival and feeding.

FIGURE 228. SWOT ANALYSIS OF WASTE ENTERPRISERS AQUACULTURE BUSINESS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Continuous free water supply ▪ Low investment costs ▪ Contractual agreement with the authority ▪ Direct contact with wholesalers ▪ Safety monitoring ▪ Economies of scale in the long-run due to low average cost and gained expertise ▪ Savings for authority and no charge to poor households	**WEAKNESSES** ▪ Requires space for pond based treatment plants ▪ Requires uncovered demand for cultivated fish species ▪ Needs efficient systems to handle possible on- and off-site health risks (e.g. high risk where fish is eaten uncooked) ▪ Requires aquaculture expertise (feeding, survival, predator and duckweed control, etc.)
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Easily replicable ▪ Significant market demand for fish ▪ Missing regulations and supportive investment climate	**THREATS** ▪ With city growth, more compact treatment plants appear ▪ Competition in alternative fish production may cause fish price to decrease ▪ Health risks reduction and monitoring costs for fish consumption may be high for the business ▪ Changing regulation and/or consumer perception of wastewater-reared fish

Contributors

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See also: www.flickr.com/photos/waste-enterprisers/sets/72157627841508651/.

Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014/16. As business operations are dynamic data can be subject to change.

Notes

1 After a test period the arrangement was changed to accelerate the maintenance process, and WE organized directly full-time plant maintenance, i.e. without need for KMA to organize this (see Figure 226, option 3).

2 The pond systems were till 2015 maintained by the local university (KNUST) and IWMI for research purposes. One of the ponds is currently (2017) used as a fish hatchery.

3 So far, mostly commercial private sector operators undertook environmental impact assessment, but not small-scale operators (Awity, 2005).

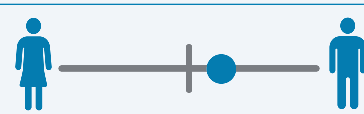
4 High survival rates were achieved with longer feeding periods (rearing fingerlings to at least 20g) and after successful removal of a large numbers of predators (snakes) from the ponds.

BUSINESS MODEL 18

Leapfrogging the value chain through aquaculture

Pay Drechsel and Munir A. Hanjra

Key characteristics

Model name	Leapfrogging the value chain through aquaculture
Waste stream	Domestic wastewater
Value-added waste product	Reclaimed water, fish feed, fresh fish and/or packaged fish, irrigated crops
Geography	Regions where inland fish is in higher demand than supply
Scale of production	Small–medium scale; 200–1,000m^3 wastewater intake per day
Supporting cases in this book	Kumasi, Ghana; Mirzapur, Bangladesh
Objective of entity	Cost-recovery [ ]; For profit [X]; Social enterprise [ ]
Investment cost range	USD 20,000 to 100,000 plus cost of suitable land/lagoons of about 1–5 ha
Organization type	Mostly public-private partnership, but also other options
Socio-economic impact	Environmental pollution reduction, health risk reduction, job creation, food security
Gender equity	Inequity likely on farm in view of access to land, knowledge and capital, while gender roles in fish marketing vary between countries 

Business value chain

Wastewater-fed aquaculture has a long tradition, especially in South and Southeast Asia, and is being recognized as an innovative business-oriented reuse system where sufficient land is available and possible health risks can be controlled, e.g. by avoiding mixed wastewater, which contains industrial effluent.

There are two different conceptual variations possible. From a safety perspective, a model as used in the presented case of Bangladesh is being preferred where the treatment process includes duckweed to absorb large amounts of nutrients, transforming them into high quality protein. The harvested duckweed is then used to feed fish grown, e.g. with groundwater in vicinity. Possible chemical contamination of the food is being monitored.

In a variation of the model, fish receives its food directly in the treatment system, where it is cultivated in the last maturation pond of multiple treatment pond set-up. To reduce health risks in this case, WHO guidelines are strictly to be observed. The treated water can be released safely in the environment, or reused for crop production in areas where irrigation water is scarce. The business model adds economic value to an existing pond-based treatment infrastructure by offering with limited additional

investments different revenue options linking into high revenue value chains. The model is suitable for small- to medium-scale operations at community or institutional level where land is available, water quality is known and fish and irrigated crops have an assured local market demand (Figure 229).

The dotted short cut can further reduce capital costs but although increases public health risks, thus can only be recommended where strict water quality monitoring is possible.

In both studied cases, the institution in charge of safe wastewater disposal teamed up with an entity experienced in wastewater treatment and aquaculture. This could be a public-private partnership (PPP), but also private-private partnerships, e.g. where a private university or hospital is teaming up with an enterprise or NGO, or only public operation. In the public-private case, the public entity provides wastewater and [a budget to set up] infrastructure for wastewater treatment and safe disposal, while the private partner offers treatment expertise and invests either in additional fish ponds and/or fish fingerlings, and assures the O&M of the overall treatment system.

The interesting aspect of the PPP is the realization of a multiple win-win situation: while the public partner gets the treatment and waste disposal done without paying for the O&M service, the private partner benefits from the – in large – already existing/budgeted infrastructure and can with very limited own capital investment produce a high-value product for revenue generation. Depending on demand and supply, the contractual agreement for using the land and/or pond system can also include a profit sharing arrangement like in the Ghana case, which allows the public entity recover some of its own operational costs. Finally, the generated revenues can allow the authorities to 'pro-poor' waive sanitation fees for the served wastewater generating households or entities.

The key players in the business set-up are the aquaculture business entity, if needed with (access to) expertise in phyto-remediation, the local municipality and/or local organization in need of wastewater

FIGURE 229. POSSIBLE REVENUE STREAMS – PROTEIN GENERATION FOR AQUACULTURE AND CASH CROP IRRIGATION

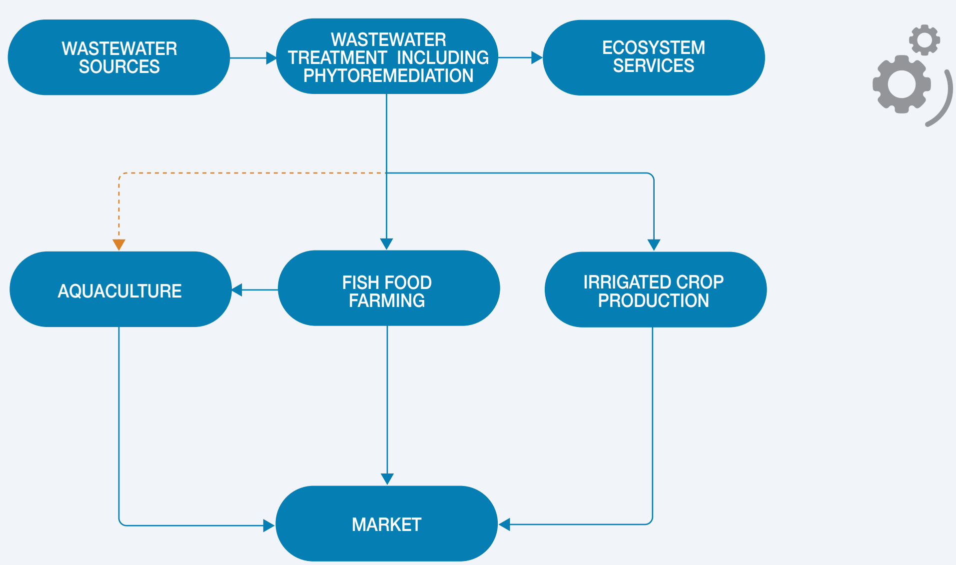
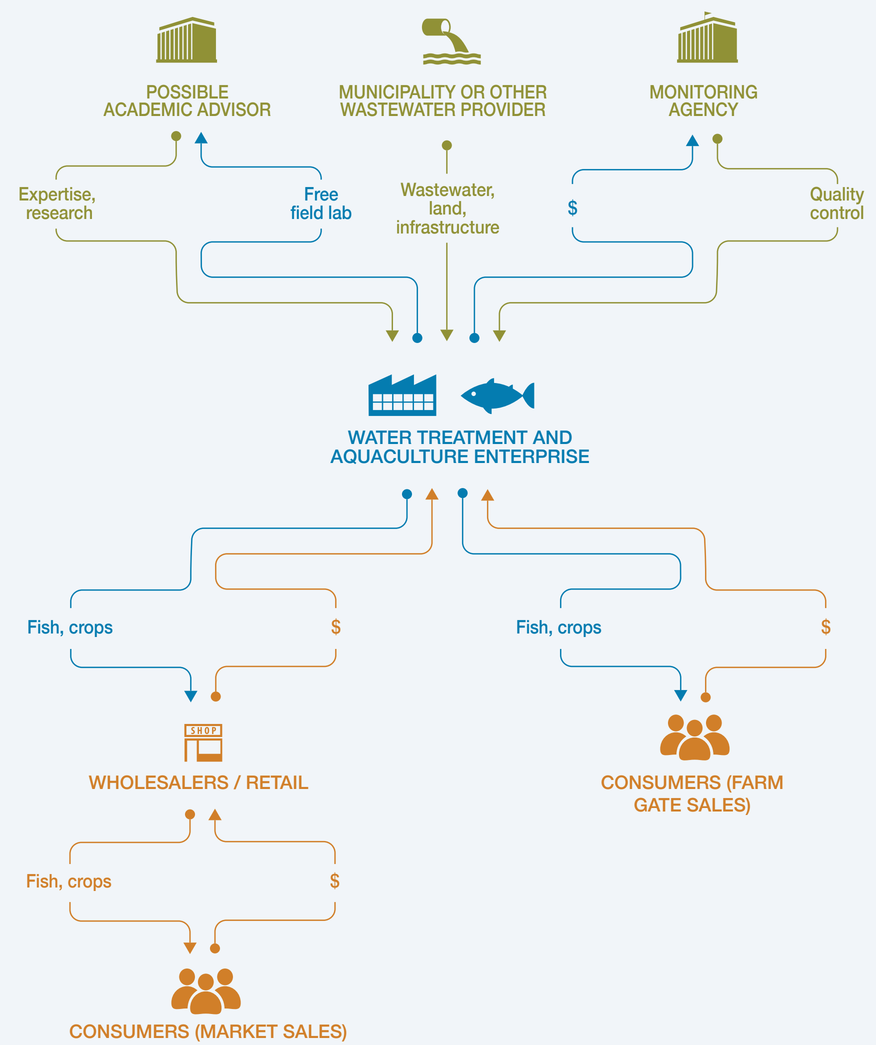


FIGURE 230. KEY PLAYERS AND VALUE CHAINS IN THE MODEL



treatment, and the local market, i.e. produce buyers and consumers (see Figure 230). An expert partner, able to carry out locally applied research in fish or duckweed farming, like a local university, could add value. Finally, an important stakeholder is the one in charge of monitoring water, crop and fish quality. Although the fish farming business will give highest priority to maintaining consumer trust, independent quality control is recommended. This could be the local agency in charge of food safety.

Given the limited capital investment needs for the enterprise, financing should be possible in many countries through a bank loan at a term of five years, best at a subsidized lending rate given the public sector support. The business has the potential to impact local residents through the production of inland fish and the creation of employment opportunities along the aquaculture value chain.

Business model

The wastewater from the community is brought to the treatment ponds through an existing sewerage network (in case of municipal wastewater treatment). Fish farming can be integrated in the treatment system or preferably be indirectly linked via the harvested phyto-biomass (e.g. duckweed). The recommended business model uses wastewater to produce on-site fish feed and with the feed off-site (i.e. not within the treatment system) fish. It offers through the sale of fish to end-users and/or intermediate traders a value proposition with a much higher revenue stream than the sale of the reclaimed water would allow (Figure 231). The business usually relies on a (public-private) partnership, which acts on an opportunity that derives from a need for both wastewater treatment and a market which can absorb more fish than on offer. The business is cost-driven, and can offer cheap produce through minimal capital costs for infrastructure, and low-cost operation. Low cost operation is enabled through the free provision of nutrient rich water and the duckweed technology which allows

FIGURE 231. BUSINESS MODEL CANVAS FROM THE PERSPECTIVE OF THE AQUACULTURE BUSINESS PROVIDER

KEY PARTNERS

- Authority in need of wastewater treatment
- Expertise / research provider
- External financier (optional)
- Fish traders

KEY ACTIVITIES

- Treat wastewater to advanced tertiary quality
- Grow duckweed and irrigate crops
- Fish farming
- Water quality monitoring
- Fish processing, marketing and sales

KEY RESOURCES

- Right to use treatment ponds for duckweed cultivation/ water treatment
- Space to establish fish ponds
- Expertise in phyto-remediation and fish farming
- Capital for fingerlings and pond construction
- Fish and crop marketing and sales

VALUE PROPOSITIONS

- Self-financed wastewater treatment building on cost-competitive fish production which takes advantage of free resources (water, nutrients, infra-structure) pond based treatment systems offer

CUSTOMER RELATIONSHIPS

- Personal (direct product sales)
- Partnership contract with wastewater-producer or authority in charge of treatment

CHANNELS

- Pond-side (farm gate) sales
- Word-of-mouth
- Local marketing channels
- Meetings, negotiation with wastewater provider

CUSTOMER SEGMENTS

- Traders and consumers of local fish and fruits and vegetables
- Authority in need of wastewater treatment

Extended Beneficiaries

- Wastewater producing households/ entities
- Fish and crop consumers
- Dwellers depending on downstream water quality

COST STRUCTURE

- Capital investment in fish and fish ponds (unless part of final treatment system)
- O&M of ponds, mostly labor incl. security against illegal fish harvest; debt repay
- Fish and crop marketing and sales
- Research collaboration (fish growth and produce safety)
- Benefit sharing with public partner (optional)

REVENUE STREAMS

- Pond-side sales of fish to customers, retail, whole sale
- Pond-side sales of crops and fish feed (if in excess)
- Payment for water treatment service (optional)

SOCIAL & ENVIRONMENTAL COSTS

- Possible human health hazard from consumption of fish grown in (proximity to) treated wastewater, where human pathogens may still exist and may be carried into human
- Laborers' health risk due to contact with wastewater, especially when harvesting duckweed

SOCIAL & ENVIRONMENTAL BENEFITS

- Wastewater efflux of organization(s) is treated, which results in reduced environmental pollution pressure to water bodies and downstream water users
- More fish protein and crops on the market at low cost
- Job creation

to produce most of the required fish feedstuff within the treatment system. Costs are also kept low due to farm gate marketing and no need for storage. Irrigated crop production offers a secondary revenue stream. Labor required for duckweed management and feeding to the fish and for fish harvesting is locally available and manpower can be trained on-site. Although the manual operations are simple which helps to save costs and to move the business towards net profits, aquaculture and even more wastewater-aquaculture requires significant management experience and skills to maintain a high fish survival rate and manage the right feeding for optimal fish growth. Partnering with an expertise provider/research institution on phyto-remediation and fish rearing will be useful unless the expertise is internally available to avoid high startup costs through 'learning by doing'. This type of enterprise may flourish at small to medium scale wherever sufficient land for both, pond based treatment and fish farming can be set up in proximity or interlinked, and where water for fishing or fish farming is generally limited. In coastal regions, possible competition from saltwater fish has to be explored. In any situation, either if fish is grown with reclaimed water (or fish is fed with plants produced in wastewater) the business requires a conducive legal-regulatory setting and quality monitoring given potential consumption as well as occupational health risks.

Potential risks and mitigation

The business model presented here was designed based on a detailed analysis of the two case studies from Ghana and Bangladesh, as well as other cases and references. There can be a variety of business risks affecting the successful implementation of such a model, most of them being more generic than model specific. For example, as reuse projects involving wastewater are potentially harmful to human and environmental health, particular health risk (mitigation) options are obvious and have to be addressed, like also community acceptance. However, also other risks such as those defined below have to be addressed, although there will be location specific differences.

Market risks: Fish is a protein-rich, nutritious source of human food and the assumption is that a strong market exists for onsite direct sale to consumers and/or sale through retail. Where the source of fish on the market is known, some consumers might not like to eat fish raised with duckweed grown in wastewater. However, it is unlikely that traders will brand their produce in a way that could jeopardize their business.

Competition risks: Fish produced on wastewater competes directly with local freshwater (or also sea water) fish and indirectly with frozen product from oversea markets, which at times could be cheaper than the local produce in some countries. Therefore, the advantage of low-cost production (using free feed) have to be used to sell the fish at a competitive price.

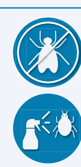
Technology and performance risks: Natural water quality remediation measures are usually low-cost. The technology of duckweed production for fish farming is straight forward and mature, and can build on decades of research and development. Local workforce can be trained in the operations. Fish farming itself requires more expertise than the water treatment as well as quality monitoring.

Political and regulatory risks: Fish farming in general is a supported agricultural practice, and there are no known political and regulatory risks in most settings. If the water used for the fish is part of the treatment chain, the business requires a legal-regulatory setting that is conducive to this situation, and thus a threat to the business might come from particular or changing safety regulations.

Social equity related risks: The model is considered to have more advantages for male entrepreneurs (farmers) although in many places cultural tradition steers if more men or women are involved in fish farming. However, in many regions, women have comparatively to men less access to land, education or capital, which are crucial for entering aquaculture. Still, there can be regionally more women working in the sector than men. In Asian countries such as Cambodia, Bangladesh, Indonesia and Vietnam, for example, women carry out 42–80% of all aquaculture activities, with equally large variations along the value chain. See also World Fish Center (2011).

Safety, environmental and health risks: The model can be very safe but requires significant attention to risk monitoring and control (Table 54). There can be specific health concerns for workers harvesting the duckweed from the wastewater, which can however be addressed with protective gear, harvesting equipment and good hygiene. In the less preferred variation of the model where fish is grown with reclaimed water, the risks extend also to the fish and thus the consumer. For this situation, the WHO (2006) guidelines for wastewater use in aquaculture apply. A common way to reduce consumer microbial

TABLE 54. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 18

RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR/ ODOR	INSECTS	WATER/ SOIL	FOOD (FISH)	
Fish farmer/operator						Consumer awareness and information has to be supported on the source of the traded fish
Community						
Fish consumer						
Mitigation measures				 	 	

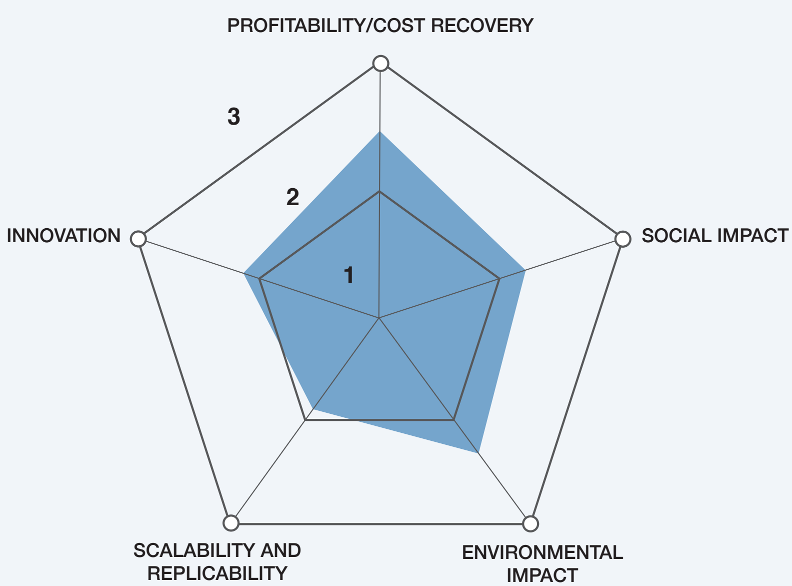
Key: NOT APPLICABLE | LOW RISK | MEDIUM RISK | HIGH RISK

risks is through fish smoking or grilling, although contaminants might survive, in particular within the fish. Purification in clean water ponds could address this challenge to some degree, as well as careful separation of meat and the digestive tract during slaughtering, and cooking. Regular monitoring of the inflowing wastewater and fish could help detect possible chemical risks, although laboratory capacity for so-called “emerging contaminants” is still missing in many developing countries.

Business performance

The business model supports the move beyond cost recovery towards profitability. The combination of ponds or zig-zag flow systems with a phyto-remediation step are applied low-cost technologies which treat wastewater to an advanced tertiary state. Using the phyto-(plant) biomass as ‘in-house’ production of fish feed, such as duckweed, and the low labor requirements of the system significantly reduces operational costs for nearby fish farming while the free use of land reduces capital cost. Where fish has a market, the system can make profits even where no subsidies are received and no wastewater treatment fees are charged. Capital costs could be further reduced where fish is grown within the last part of a pond based system. However, this variation of the model is significantly increasing health risks and can only be considered where water quality and risk mitigation measures fully correspond with safety recommendations. The model ranks also high in terms of environmental impacts due to the wastewater treatment, in particular nutrient removal, and on social impact due to protection of public health, plus the additional supply of nutritious fish and local jobs (Figure 232). The model ranks lowest on scalability and replicability criteria due to its land requirements. Yet, the business model highlights strong potential for replication for a developing country setup with limited institutional capacities and its applicability to peri-urban areas and towns where land is not yet in short supply. The model is thus attuned to the needs of small- and medium-size communities where high tech wastewater treatment plants will not achieve cost-economies and/or might not be affordable. The system can be scaled to the needs of the local communities as the inputs are as simple although

FIGURE 232. RANKING RESULTS FOR AQUACULTURE BASED BUSINESS MODEL



the rearing of fish should not be underestimated and requires an experienced partner. Further, the regulatory setup should support production and sale of fish from such a system, even if fish is only indirectly in contact with the water. There exists a greater potential for this model in countries that are land-locked (no sea food), have limited surface water resources while fish is a welcomed staple food in the local diet.

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16. BUSINESS MODELS FOR COST SHARING AND RISK MINIMIZATION

Introduction

Public resources, including Official Development Assistance (ODA) are not sufficient for achieving the Sustainable Development Goals (SDGs) targets in particular in the waste management and sanitation sectors with strong regional funding gaps. Private finance appears critical and the sector is increasingly looking to emerging and frontier markets for investment opportunities. However, current levels of private investment in sectors related to the SDGs are relatively low. Only a fraction of the worldwide invested assets of banks, pension funds, insurers, foundations and transnational corporations is in sectors critical to the SDGs (World Economic Forum, 2015). Translating these assets into SDG-compatible investments will be key, with the potential being greater in sectors related to the circular economy, including infrastructure (power, renewable energy, water and sanitation). Yet, despite growing interest, significant barriers to private sector engagement remain at all levels, including inefficient financial markets, weak institutions, regulatory frameworks and enabling environments, and macroeconomic and political instability (see also Chapter 19). All these barriers contribute to a more risky, challenging, and uncertain environment for investors, particularly when compared to more developed markets where beneficiaries do not face affordability constraints (and governments can set tariffs at cost recovery level) to balance the risk and reward of investments.

Investment guarantees are designed to mitigate risk for private and/or public sector financing. These can be guarantees for public projects (Partial Credit Guarantees) and for private projects (Partial Risk Guarantees; PRG) with counterguarantee from the member government. There can also be political risk insurance as offered by the World Bank's Multilateral Investment Guarantee Agency (Box 9).

Especially important for private investors are PRGs which cover private lenders against the risk of a public/governmental entity failing to perform its obligations with respect to a private project. Eligible projects are public-private partnerships (PPP) such as Build-Operate-Transfer (BOT) projects. PRGs can cover a range of risks including, changes in law, failure to meet contractual payment obligations, obstruction of an arbitration process, expropriation and nationalization, foreign currency availability and convertibility, failure to issue licenses, approvals and consents in a timely manner, etc.

Also, public investors can strategically use their funds to mitigate investment risk and/or enhance returns for private investors by supporting blended finance transactions. Blended Finance is the strategic use of development finance and philanthropic funds to mobilize private capital flows to

Box 9. Multilateral Investment Guarantee Agency (MIGA)

MIGA offers political risk insurance and can cover equity, shareholder loans and loan guarantees issued by equity holders; it can also cover loans by third party institutions, usually commercial banks, provided that a shareholder's investment in the project is also being insured by MIGA. Like other investment insurers, MIGA can provide broad coverage to investors against such risks as currency transfer, war and civil disturbance and expropriation; it can customize these coverages to suit the particular needs of investors. MIGA can normally issue coverage within a few months of an investor's application since it does not enter into counter-guarantee arrangements with the host country government of the project. MIGA is also a key partner in the presented case study from Jordan.

Source: http://siteresources.worldbank.org/INTGUARANTEES/Resources/Guarantees_Q&A_03172009.pdf

emerging and frontier markets to do more with limited public funds. Blended Finance enhances the impact of limited philanthropic and development resources by using those funds to tap into the dollars of private capital available in global markets. It offers promising potential as an ecosystem solution to close the development funding gap. Estimates suggest that public capital deployed through Blended Finance transactions can attract one to ten times the initial amount in private investment.

The public-private partnership setup of the As Samra wastewater treatment plant in Jordan was hailed for its innovative financing model, using government funds and donor grants to leverage private sector investments. Taking the business model of As Samra as example, the described model highlights the key components of the financial set up rather than the operational side of the plant as the approach could prove beneficial in other contexts. How the model was implemented in the case of As Samra is presented as case study.

While the financial set up can be applied to many large-scale treatment plants, independently of their efforts towards resource recovery and reuse, the model is particularly relevant for realizing social and environmental benefits which “treatment for reuse” projects offer in water-scarce regions, in particular if they fall short of financial viability.

The most common cost and risk sharing mechanism to support projects that are economically justified but not financially viable, is **viability gap funding**. Through targeted investment of public or donor funds in infrastructure development costs, private sector can be enticed to assume responsibility for construction, operation and maintenance of the facility, provided the venture becomes profitable and bankable. Especially in cases with fixed or capped water user tariffs, cost recovery options require intensive analysis and negotiation. The viability of the project is supported through a highly efficient energy recovery mechanism, which is significantly reducing operational costs.

For the model to work, several framework conditions are indispensable. A stable regulatory and political environment is prerequisite for partners to engage, especially for large-scale and long-term ventures. The combination of multiple public and private funding channels creates an interdependence of payment streams because each contribution will only pay off if the other parties fully comply with their commitments. All partners need to negotiate comprehensive contractual and risk mitigating agreements to provide necessary guarantees and remedies.

If these conditions are met, the public-private partnership setup can lead to state-of-the-art wastewater treatment facilities and management processes with large efficiency gains compared to traditional models. The public investment, albeit a grant contribution, leverages additional funds from private investors and can thereby deliver wastewater treatment services more efficiently and at larger scale. The provision of safe, treated water for reuse in agriculture and industrial operations contributes to economic development and environmental protection, especially in water-scarce regions.

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CASE

Viability gap funding (As Samra, Jordan)

P. Drechsel, G.K. Danso and M.A. Hanjra

Supporting case for Business Model 19	
Location:	As Samra, Amman, Jordan
Waste input type:	Wastewater
Value offer:	Treated wastewater, hydropower, biogas, carbon offsetting
Organization type:	Public-private partnership (PPP)
Status of organization:	New treatment plant completed in 2008 and extended between 2012 and 2015
Scale of businesses:	Large scale
Major partners:	Samra Wastewater Treatment Plant Company Limited; Millennium Challenge Corporation; Government of Jordan; Consortium of banks

Executive summary

Water scarcity puts water reuse very high on Jordan's development agenda. The As Samra wastewater treatment plant (WWTP) which is the largest in the country was purposely designed to support agricultural production in the Jordan Valley that relies increasingly on treated wastewater for irrigation purposes. Set up as a public-private partnership (25-year BOT contract) the WWTP is located near Amman. Building on an older pond-based treatment plant, a new WWTP was constructed between 2003 and 2008 (phase 1) and expanded from 2012 to 2015 (phase 2) with financial support from the United States Agency for International Development (USAID; phase 1) and a Viability Gap Funding by the Millennium Challenge Corporation (MCC, phase 2), to reach a capacity of 364,000m^3 per day. Under the coordination of the Ministry of Water and Irrigation, the construction was facilitated by a 20-year commercial loan, the longest maturity that Jordanian banks have ever offered so far, and a comprehensive risk sharing arrangement. The contractual structure developed for the As Samra expansion (2012–2015) has a high replication potential elsewhere in the world, to allow projects that are economically and environmentally beneficial to be implemented and operated by the private sector also where such projects would otherwise be unaffordable to the public sector. The expanded As Samra Wastewater Treatment Plant was inaugurated in October 2015 to provide Jordan with up to 133 million cubic meters of treated water per year. Already today, treated wastewater is representing 13 percent of Jordan's entire renewable water resources, freeing up fresh water for more valuable uses. Ten percent of the country's agricultural water consumption comes from the As Samra plant. In addition, the As Samra plant is able to generate up to 95% of its energy needs, supported in part by a favorable topography. The production of renewable energies allows the plant to reduce its carbon footprint by about 300,000t of carbon dioxide (CO_2e) per year.

KEY PERFORMANCE INDICATORS (2015/16)						
Land use:	About 400 ha owned by the Ministry of Water and Irrigation (MWI)					
Water treated:	A design capacity of 364,000m^3 per day able to serve about 3.5 million capita					
Capital investment:	Phase-1 (2003–2008) USD 169 million; Phase-2 (2012–2015) about USD 223 million[1]					
Labor employment:	About 180–210 permanent local employees, of which about 70 are skilled workers; plus up to 2,500 during the construction phases					
Operation and maintenance cost:	Full cost recovery (at the time of study USD 1.3 million per month)					
Outputs:	364,000m^3 per day wastewater treatment capacity 90–95% energy self-sufficiency; 300,000t CO_2e per year carbon savings 118t of dry sludge (DS) per day in 2011, to increase to 194t in 2025					
Potential social and/or environmental impact:	Significantly improved water quality, less contamination of soil and groundwater, reduced carbon foot print; treated water for irrigation; livelihoods support for irrigating farmers, plus 180–210 new jobs at the WWTP					
Financial viability indicators:	Bank loan back period:	13–20 years	Post-tax IRR:	10–18% (t.b.c.)	Gross margin:	undisclosed

Context and background

The Hashemite Kingdom of Jordan covers a territory of about 90,000 km^2. Rainfall is confined largely to the winter season and ranges from around 660mm in the north-west of the country to less than 130mm in the eastern and southern deserts, which form about 90% of the surface area. Under low rainfall, high evaporation and increasing crop intensification, Jordan is since long over-exploiting its available water resources with severe consequences for the Lower Jordan River Basin and the Dead Sea where over the last decades decreasing amounts of water arrived (Courcier et al., 2005).

Wastewater collection and treatment services were provided to about 63% of the Jordanian population in 2013, producing about 137 million cubic meters (MCM) of treated wastewater annually that is being reused primarily in agriculture. The remaining population uses septic tanks and cesspits in rural and dispersed settlements. With the increasing population and the country's social and economic development, the amount of treated wastewater is growing. It is estimated that by 2030, the volume of treated wastewater will be 240 MCM. Currently, more than 70% of the wastewater treated in Jordan comes from the As-Samra wastewater treatment plant which underwent between 2003–2008 and 2012–2015 major construction work. The plant replaced an overburdened stabilization pond system which was despite some extension work no longer able to maintain effluent water quality at acceptable levels. Its treated effluent is collected in the King Talal Reservoir (KTR) which is supporting most of the farming in the Jordan valley. In the KTR, the wastewater gets mixed with rain/freshwater from the Zarqa river basin. The mixed water irrigates about 20,000 ha in the middle and lower Jordan Valley, replacing its dwindling freshwater flow (Seder and Abdel-Jabbar, 2011). The wastewater flow is facilitated by a favorable topographical situation, allowing a low-cost transfer of urban wastewater via As Samra to the irrigation areas (McCornick et al., 2004; Courcier et al., 2005). Amman, the capital of Jordan, produces the bulk of the wastewater treated in As Samra.

About 80% of the agricultural water consumption and production in the lower and middle Jordan valley depends on blended wastewater (World Bank, 2016). Fruits and other cash crops form the major component of reuse in the Jordan valley. Aside indirect wastewater reuse of treated wastewater mixed with fresh water, also direct use (i.e. of unmixed wastewater) exists to a smaller extent in the vicinity of As Samra.

Market environment

While globally many WWTP have smaller reuse activities, As Samra is an example of a WWTP with a strong double value proposition (Wichelns et al., 2015), where the national water scarcity makes the production of water 'fit for reuse' of equal if not larger importance than the provided sanitation service.

The demand for the As Samra plant stimulated a range of institutional, financial and regulatory innovations to make the project happen. The plant represents the first private sector co-financed BOT project in Jordan, as well as the first public-private partnership in financing and management of a public infrastructure project in the country, using a mixed financing model that accommodates that neither water reuse nor the water tariff will be major revenue streams.

The market acceptance and penetration of mixed fresh/wastewater is high and competition is almost none as fresh water resources are fully exploited. Given population growth, which is expected to exceed 7.8 million by 2022, increasing fresh water abstraction or reallocation for domestic needs implies also more available wastewater for irrigation. The benefits of safely treated wastewater are well recognized by most stakeholder, especially in the public sector (Carr and Potter, 2013). In summary, the Jordanian market for further reuse-oriented WWTPs is very positive, and Jordan is not the only water-scarce country in the subregion.

Macro-economic environment

The inclusion of wastewater reuse in the country's National Water Strategy since 1998 was an important signal of placing high priority on the value of reclaimed water. The 2016–2030 National Water Strategy and the national substitution policy consider treated wastewater effluent as a core water resource that has been added to the water budget, with priority given to agriculture for unrestricted irrigation. The main pillars of the national substitution policy are public acceptance, suitability and adequacy of high-quality water, sustainability and enforcement of laws. As a result, treated wastewater has been used in place of fresh water (recommended in the National Wastewater Management Strategy) in accordance with the quality guidelines and standards of the World Health Organization (WHO) and Food and Agriculture Organization (FAO), to produce an effluent fit for reuse in irrigation (MWI, 2016). Table 55 shows the estimated value of water in different sectors. MWI strategy is to increase the use of unconventional and reclaimed water for industry and agriculture as much as possible in order to save fresh water for domestic use (which includes the tourist sector).

Jordan has also taken significant steps to encourage foreign investment. Several sectors have experienced key reforms in recent years. Foreign and domestic investment laws grant specific incentives to industry, agriculture, tourism, hospitals, transportation, energy and water distribution. The Public Private Partnership Law from 2014 aims to encourage the participation of the private sector in the Kingdom's economic development and provides a legislative environment for joint projects (U.S. Department of State, 2015). Following sector reforms, agriculture in Jordan is now virtually free of

TABLE 55. ECONOMIC BENEFIT FROM WATER USED, BY SECTOR

SECTOR	FINANCIAL RETURN USD/M^3 OF WATER	JOB OPPORTUNITIES PERSON/MCM OF WATER
Agriculture	0.36	148
Tourism	25	1,693
Industry	40	3,777

Source: MWI, 2016; Closson et al., 2010.

restrictions and all direct subsidies have been removed. Credit to agriculture at low interest rates is the single most important conduit for government subsidies to agriculture.

Critical challenges to agricultural development are water scarcity and the need for increasing water use efficiency as Jordan is among the world's most water deficit-countries. Its per capita share of renewable water resources is according to different sources between 106 and 156m^3 per year, which is even lower than the "absolute water scarcity" threshold of 500m^3 per person per year (Rijsberman, 2006). Despite limited arable land (2.4%), the agricultural sector is the largest water user (65–75% of the country's water resources) absorbing almost all treated wastewater. Although the agricultural contribution to Jordan's GDP appears with about 4% small, an estimated 28% of the national GDP is considered agriculture-dependent due to strong upstream and downstream linkages. The arrival of the Arab Spring in early 2011 had a profound effect on market confidence in the region. While the events of the Arab Spring did not directly impact Jordan, they inevitably raised the risk bar and prolonged completion of the transaction.

Business model

A public-private partnership (PPP) model was developed to finance the construction and operation of the As-Samra plant, with funding provided initially by USAID (construction phase I: 2003–2008), and for further expansion and technological upgrade by MCC (construction phase II: 2012–2016). The PPP is based on a 25-year Build-Operate-Transfer (BOT) contract signed in 2003 which was extended in 2012. Through this PPP, the government (MWI) delegates responsibilities to a private sector entity to finance, design, build, operate and maintain the facility for a 25-year period. The private sector entity is the Samra Wastewater Treatment Plant Company Limited (SPC), a private company whose investors include Morganti, an American affiliate of the Consolidated Contractors Group, Suez Environment, a Paris based utility company, and Infilco Degremont, an American company, since mid-2015 a subsidiary of Suez Environment. The Jordan-based Arab Bank arranged a consortium of nine local and international financial institutions to provide a commercial loan in local currency with a term of up to 20 years, the longest maturity in Jordan to date, with an initially fixed, then floating interest rate. Under this public-private partnership, the government of Jordan benefits from having the private sector both (i) raise the financing for and (ii) guarantee the high-quality construction, operation and maintenance of the facility. At the end of the concession period, in 2037, the facility will be transferred back to the government of Jordan in good working order and at no additional cost.

MCC funded USD 93 million of the USD 275[2] million cost of the As-Samra phase 2 expansion project, the Government of Jordan at least USD 19.8 million, the private sector sponsors contributed an equity injection of USD 8.6m (brownfield investment based on reinvesting phase 1 cash flows into the expansion) and the association of banks about $148 million. The MCC support is leveraged through the lenders and private sector's co-financing of more than 50% of the expansion cost. By bringing down the capital costs, the MCC grant enabled the project to be financially viable, thus benefiting the government and local rate-payers, while making the project attractive for SPC and local Jordanian banks. However, MCC's grant does not subsidize the private sector, as the private investors earn a return only on their portion of invested capital. The As Samra WWTP was the first in the Middle East to use a combination of private, local government and donor financing, using a **Viability Gap Funding** scheme (see related Box in Business Model 19) to bring down the capital costs via the MCC contribution. Closing the financing of the expansion supported its feasibility and demonstrated the significant benefits of combining private sector financing with viability-gap grant funding.

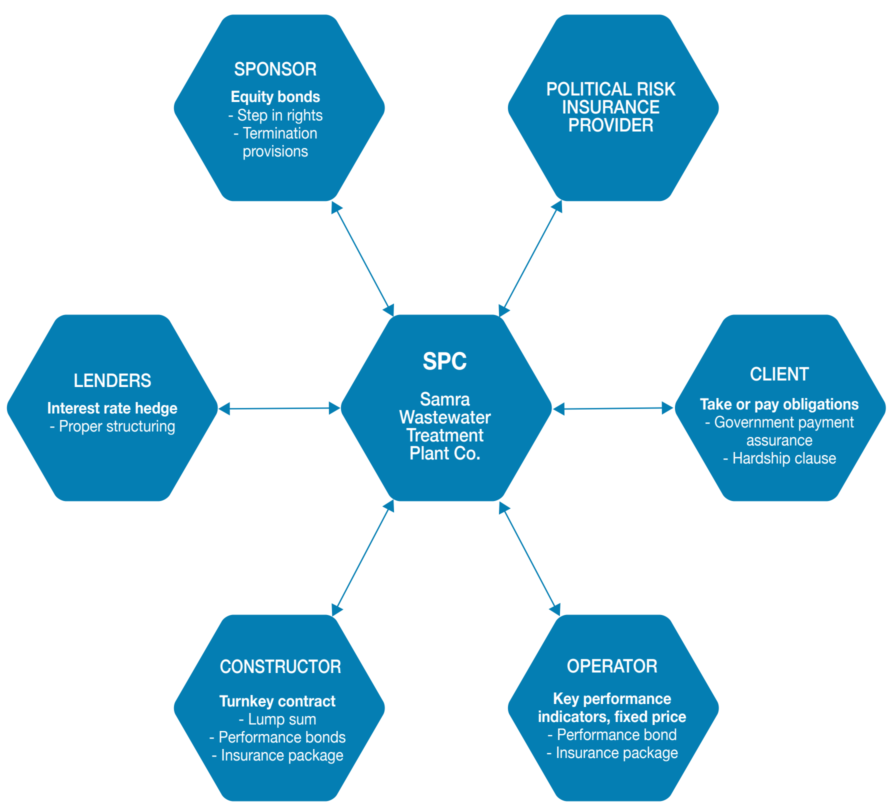
As unique as the template is, it has its challenges. The setup of the blended finance was complicated by MCC's inability to enter into any direct contractual relationships with the project sponsors (private

sector) or the lenders (banks). Moreover, both MCC and the lenders were reluctant to fund ahead of each other; as a result, financial close and satisfaction of the initial conditions to the MCC disbursement had to occur on the same day (Keenan and Norman, 2012). This situation is indicative of another cornerstone of the business model, which is **risk sharing** as a necessity to attract investors (Figure 233; adapted from SPC, 2014).

Given the size of the plant and the current water tariff and fee structure, the finance model does not rely to any significant degree on revenues from the wastewater-generating households, e.g. in Amman, Zarga and Russeifa, or fees from wastewater using farmers. In contrast, the applied finance model allows to keep the treatment tariffs very affordable (stated objective). This is supported by a significant measure to keep the WWTP energy efficient and in large self-sustainable and in this way the largest operational cost factor within limits.

Jordan's water tariff includes a wastewater levy which is based on the freshwater consumption. However, this is not sufficient to cover O&M cost of wastewater treatment, also if farmers water reuse fees are added. Farmers are charged differently depending on the scheme they are connected. Some pay per cubic meter consumed, others have an allocated amount of water and pay a lump sum. However, the fee for reclaimed water cannot exceed the one paid for the preferred freshwater (Rothenberger, 2010). According to Bahri (2008), farmers in the vicinity of WWTPs pay the MWI USD

FIGURE 233. SELECTED RISK MITIGATION COMPONENTS OF THE AS SAMRA BOT MODEL



143–286 per ha and year, while those using mixed water pay the Jordan Valley Authority (JVA) USD 0.07 per m^3. During the rainy winter season, water is provided for free for salt leaching. However, the revenues of the JVA are so far not recorded at As Samra (or the Government) as the Water Authority of Jordan (WAJ) provides JVA with free supply of wastewater services from As Samra (OECD, 2014). Both authorities are reporting to the Ministry of Water and Irrigation.

Value propositions

In the water stressed situation of Jordan, the essence of the business model is the double value proposition of wastewater treatment and the recovery of as much reclaimed water as possible for further usage, especially crop irrigation (an increase from 61 to 83%), that high quality freshwater can be reserved for domestic (including potable) purposes benefitting 2 million people. This objective has been achieved with an innovative blended finance and risk sharing mechanism which makes the capital investment attractive and bearable for all parties, and covers in addition the operational costs (through the BOT arrangement, supported by a high level of energy recovery and potentially carbon credits). The model allows the WWTP to achieve financial viability despite low user tariffs (Figure 234).

Asides the main objective of supporting irrigation in the Jordan Valley, the plant also offers its direct proximity job opportunities and water for irrigation. There are about 300–500 ha within and around the As Samra plant premises planted with forage crops (clover), olive trees and, for example, sorghum. Most farmers have irrigation water rights and contracts with the Ministry of Irrigation. The irrigation method applied is surface and drip irrigation, often gravity based. The amount of irrigated water used is open and there is no particular system in place to regulate use. In addition, many farmers pump water directly out of the Zarqa river without any formal arrangement with the MWI. There are periodical field inspections to prevent the cultivation of leafy vegetables.

Also livestock owners benefit. According to farmers, the availability of wastewater irrigated forage has simplified the production of sheep and goats instead of relying on natural grazing in the surrounding areas. This is a significant advantage given that the local area has a poor natural vegetation cover due to the scarcity of rainfall (Seder and Abdel-Jabbar, 2011).

The plant also produces sludge and (biogas) slurry with a high potential for soil amelioration (e.g. for forestry) or the cement industry, once the regulatory framework becomes supportive. Given the significant amount of sludge the WWTP will generate, the MCC considers local storage only a temporary solution. The plant operator and the Government of Jordan have agreed to work together to provide alternative solutions including related policies, procedures and standards for an environmentally and socially sound permanent disposal and/or re-use of sludge[3]. A viable market for sludge produced by the plant is yet to be found, given the restrictions that apply. Until this happens the parties will continue to store and dispose of sludge in accordance with the terms of the concession agreement.

Institutional environment

The Ministry of Water and Irrigation (MWI) has overall responsibility for policies and strategies in the water sector, including water and wastewater supply and related projects, planning and management. Under MWI operate, among others, the (i) Water Authority of Jordan (WAJ) which is responsible for water supply and wastewater services, as well as for water resource planning and monitoring, construction, and operations; (ii) the Project Management Unit (PMU) within WAJ, which regulates water supply and wastewater utilities, promotes private sector participation in the water sector and carries tasks related to project planning and execution; and (iii) the Jordan Valley Authority (JVA) which manages water resources and provides bulk water in the Jordan Valley. The main institutions involved in the As Samra WWTP (Figure 235) and their roles are (SPC, 2014):

FIGURE 234. BUSINESS MODEL CANVAS OF AS SAMRA WASTEWATER TREATMENT PLANT FROM THE PRIVATE SECTOR PERSPECTIVE (SPC)

KEY PARTNERS

- Government of Jordan
- MCC: grant funding
- Bank consortium: loans
- MoF
- MIGA: credit risk insurance

KEY ACTIVITIES

- Design and construction of plant
- Treatment of wastewater
- Provide safe, treated water for agriculture / industry
- Hydropower and biogas generation
- Operation of plant for fixed period, then handover to government

KEY RESOURCES

- Funding from various (MCC grant, bank loans, private equity, MoF fund)
- Private sector technology and expertise in construction, operation and maintenance

VALUE PROPOSITIONS

- Treat wastewater and provide safe, treated water for reuse in agriculture and industry, freeing up freshwater for domestic use
- Internal energy recovery (95%)

CUSTOMER RELATIONSHIPS

- Government pays SPC per unit of treated water
- Government collects fees through water user tariffs
- Users of treated water in agriculture and industry pay fees to government

CHANNELS

- Direct / brokered negotiation with GoJ
- Existing conveyor pipeline to transport water from cities, and stream directing the treated waters to King Talal Dam

CUSTOMER SEGMENTS

- SPC provides water treatment service to government
- Wastewater from households and industry treated
- Wastewater reused in agriculture / industry

COST STRUCTURE

- Capital cost and upfront infrastructure investment
- Operating costs and maintenance

REVENUE STREAMS

- SPC is paid by government per unit of treated water
- Energy recovery allows significant operational cost savings

SOCIAL & ENVIRONMENTAL COSTS (cf. Consolidated Consultants, 2012)

- Infrastructure requires land and affects eco-system on site
- Health risk due to laborers' possible contact with wastewater and (during construction) impacts on air quality and noise
- Possible ecological impact from mixing freshwater and treated wastewater
- Potential health effects of using diluted wastewater to produced vegetables

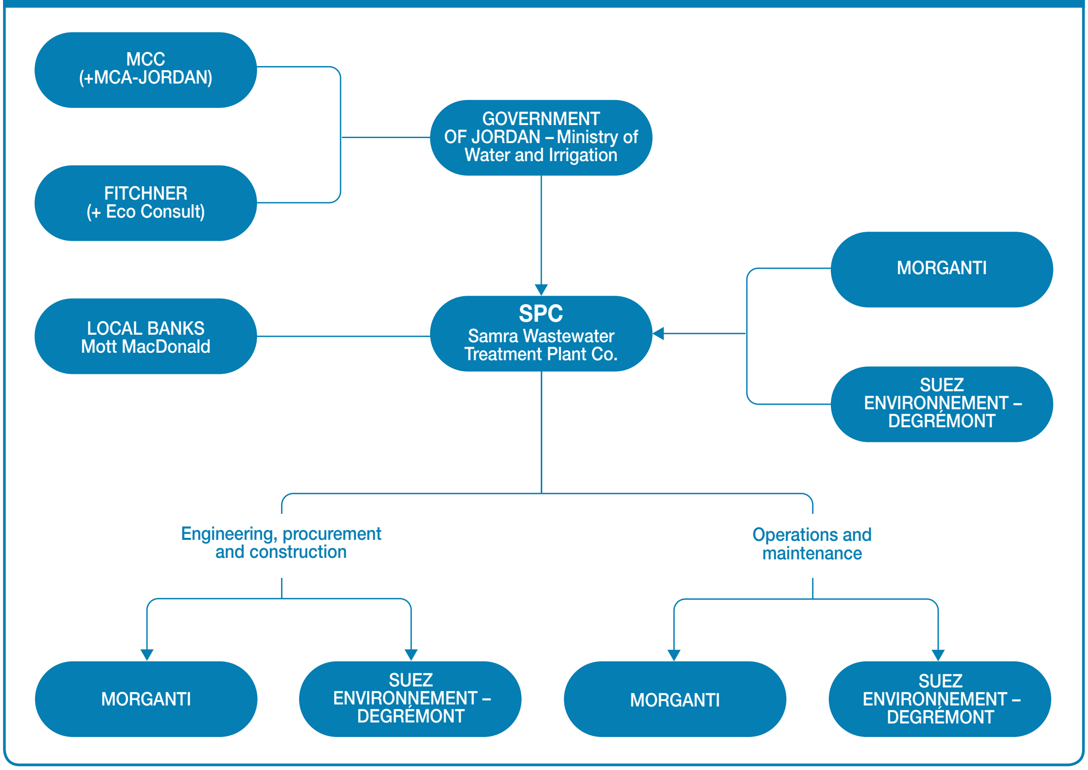
SOCIAL & ENVIRONMENTAL BENEFITS (cf. Consolidated Consultants, 2012)

- Increased resource efficiency through water reuse
- Reduced pollution of receiving waters, reduction in public health expenditure associated with disease outbreak
- Improvement in groundwater level because of the additional water sources, improved irrigation technology and protection
- Job creation at the plant and downstream
- Use of treated water in agriculture and industry supports economic development
- Government steps in for cost recovery and can maintain low water tariffs for inclusive access to services

- Client: Government of Jordan; represented by the Ministry of Water and Irrigation (MWI).
- Donor (Phase 2): Millennium Challenge Corporation (MCC); U.S. foreign aid agency.
- Grant Fund Manager: Millennium Challenge Account (MCA-Jordan).
- Authorities Engineer: Fichtner (+ local consultant Eco Consult), also in charge of compliance monitoring with the health, safety and environment management plan.
- Project Companies: Samra Wastewater Treatment Plant Company Ltd. (SPC) and Samra Plant Operation and Maintenance Co. Ltd. (O&M).
- Sponsors: Suez Environment / Infilco-Degremont and Morganti- Consolidated Contractors Group.
- Lenders: Lender Syndicate led by Arab Bank; Lenders technical advisor: Mott MacDonald.
- Political risk insurance: Multilateral Investment Guarantee Agency (MIGA) of the World Bank.
- Beneficiaries: Mainly Amman, Russeifa and Zarqa populations as well as local towns in plant vicinity (e.g. Hashimiyya) and farmers irrigating crops with treated wastewater in the vicinity of the plant and across the Jordan valley.

An overview about relevant laws and bylaws, standards and regulations as well as the requirements of the funding agencies, of relevance for the WWTP, has been presented by Seder and Abdel-Jabbar (2011) and Consolidated Consultants (2012). Of particular relevance in the **agricultural** context are the 2006 standards for safe water reuse (JS 893/2006) which allow for a wide range of water reuse activities for highly treated reclaimed water for landscapes, cut flowers and high-value crops (except crops eaten uncooked), and for smaller scale treatment reuse activities with restricted cropping patterns. Reuse categories for treated wastewater are:

FIGURE 235. MAIN INSTITUTIONAL SET UP



Source: SPC, 2014

- Recycling of water for irrigation of vegetables that are normally cooked.
- Recycling of water used for tree crops, forestry and industrial processes.
- Discharges to receiving water such as wadis and catchment's areas.
- Use in artificial recharge to aquifers not used for drinking purposes.
- Discharge to public parks or recreational areas.
- Use in irrigation of animal fodder.
- Use of reclaimed water for cut flowers.

Although the 2006 standards were a big step forward (McCornick et al., 2004), Abdel-Jabbar (2009) argues that the existing water thresholds are often too stringent and less suitable than the multi-barrier risk reduction options promoted by WHO (2006). The author recommends updating JS 893/2006 towards a more accommodating model, supported by on- and off-farm risk mitigation measures. Although treated wastewater mixed with freshwater might no longer be labeled 'treated wastewater' (Carr and Potter, 2013) the government recommends that all crops irrigated with treated or mixed waters shall be analyzed and monitored periodically (MWI, 2010).

Technology and processes

The wastewater generated for example in Amman, where 80% of the households are connected to a sewage network, is transported over about 40 km to As Samra by gravity through a conveyor pipeline. During the year 2010, the maximum inflow ranged between 210,000 and 230,000m^3/day. Wastewater is under high pressure when arriving at the plant due to difference in elevation, and turbines have been installed to run on upstream wastewater flow, thereby generating renewable energy that is used on site. The same process is repeated after treatment where the effluent is used to power discharge hydraulic turbines generating additional energy before the water is released towards the KTR with its 86 MCM storage capacity.

The activated sludge treatment process consists of pretreatment and primary settling tanks, aerobe and anaerobe biological treatment, biomass settling and chlorination. Water quality changes between in- and outlets are shown in Table 56 (Consolidated Consultants, 2012; Suez, 2015).

Sludge from primary treatment and the aeration tanks undergoes thickening and anaerobic digestion, dewatering (target 18% dry solids) and sun drying (target 50% dry solids) (Suez, 2015). The daily sludge generation was in 2011 about 118 tons of dry sludge or 393 tons of sludge (at 30% dry solids). Given the current legal limitations for sludge reuse, MCC and SPC are given the exploration of alternative sludge disposal/reuse options, such as cement kiln or land application, highest priority (Consolidated Consultants, 2012) as space for future storage is declining and the potential negative environmental impact unacceptable for the WWTP's staff and people living in the area.

The company has implemented an energy management system as per ISO 50001 to evaluate and control its energy consumption. Between 80 and 95% of the plant's energy requirements are met using the in- and outflow turbines (1.7 and 2.5 megawatts, respectively) and the biogas generation from sludge (9.5 megawatts). An innovation was the use of hydraulic turbines on raw sewage water.

TABLE 56. WATER TREATMENT QUALITY AS SAMRA

WATER QUALITY INLET		WATER QUALITY OUTLET	
BOD_5	637–708 mg/l	BOD_5	5–30 mg/l
TSS	649–682 mg/l	TSS	15–30 mg/l
Total Nitrogen	100–107 mg/l	Total Nitrogen	15–30 mg/l

The expected increase of the wastewater inflows from the city of Zarqa will pose some challenges as its location is lower than the plant which will affect the power recovery ratio. This can in part be compensated by increasing the capacity of the biogas power generation system and a reduction of the power consumption by the aeration units.

Funding and financial outlook

Like across the region, Jordanian water tariffs do neither cover the water production cost nor the wastewater treatment costs. While MWI (2010) suggests that wastewater charges, connection fees, sewerage taxes and treatment fees shall be set to cover at least the operation and maintenance costs (ultimately aiming at full cost recovery), the As Samra BOT blended finance model allows to keep the plant also under the current (social) tariff structure viable over the 25-year contract period. To achieve this, the government pays for SPC's provision of wastewater treatment services about USD 0.17/m^3 (pers. communication with the plant manager, 2014).[4] Running at the targeted capacity of 133MCM per year, this would result in an annual governmental subsidy of USD 22.6m. This can be partially recovered in various ways. Household (waste)water tariffs contribute the largest share of about 60% on average over all WWTPs (MWI, 2013). If As Samra would have its own account, it could probably break even as its O&M costs are much lower than of other WWTPs, given its energy efficiency (MWI, 2015). Lower contributions could be expected from the agricultural sector (see above) and potentially through the carbon market. The UNFCCC (2010) application for registration under the Clean Development Mechanism (GHG reduction of 296,704t of CO_2e per year) is at the validation step.[5] Another (more lucrative) revenue source planned for 2021 is the possible sale of wastewater to Power Plants in the order of 22.5 MCM per year at USD 0.63/m^3 resulting in an estimated annual cost recovery of about USD 14million. Tariff adjustments would help reducing the governmental share. This applies more to As Samra (if budgeted separately) than other WWTPs in Jordan as in other cases energy tariff increases would undermine possible savings (MHI, 2013).

Socio-economic, health and environmental impact

An environmental and social impact assessment (ESIA) was prepared in January 2012 for the Samra WWTP expansion. The project sponsors' consortium then prepared a health, safety and environment (HSE) management plan based on the standards of all (national and international) partners to mitigate potential environmental and social risks and impacts during the construction period, while during operations environmental and social risks and impacts are managed by the SPC based on their "Quality, occupational health, safety and environment" (QHSE) management system.

Positive impacts of the As Samra wastewater treatment plant largely accrue as a result of improved quality of domestic and industrial sewage effluents entering ultimately surface water bodies. The treatment plant reduces disposal of raw sewage, risks of groundwater pollution and the spread of excreta-related diseases. Since the commissioning of As Samra, water quality in the King Talal Reservoir and the Zarqa river have significantly improved despite some recontamination (Al-Omari et al., 2013; Abdel-Jabbar, 2009) allowing fish to return. The plant is providing directly about 170–180 new jobs, nearly exclusively used by national staff. As so far only 3% of all employees are female, women's associations were contacted to encourage the participation of women in public consultations about job opportunities, and to analyze and address the barriers of women employment at the Samra WWTP. Finally, the treated wastewater is supporting about 10,000 jobs in agriculture. At the aggregate level, the treatment plant has significant indirect benefits for the whole country as improvements in wastewater use deliver fresh water savings for domestic use by an estimated 2 million people, reduce aquifer extractions, support the tourist sector and related jobs, food security, and adaptation to the risks of climate change and migration. As Samra is also producing 103,000 kwh green energy per day, making the plant 90–95% energy self-sustainable.

A challenge is sludge management. The drying lagoons and bio-solid storage lagoons provide a favourable environment for mosquito, fly and insect growth. The ESIA states that 15% of flies that originate at the project site can reach the nearest residential areas. Mitigation measures like fumigation have been put in place, but an extension of sludge drying could reach acceptability limits. The As Samra plant is in general designed to ensure that no odor nuisance occurs and the plant obtained highest certificates for health and safety as well as environmental protection (Suez, 2015). Risks and impacts related to groundwater infiltration were considered as low due to the physical characteristics of the sludge and 80m deep groundwater table.

Scalability and replicability considerations

The finance of water recovery and use becomes more favorable when treatment costs are low and the value proposition goes beyond recovering water from wastewater and includes for example the recovery of nutrients and energy (see below). In such cases, the likelihood of recovering both the fixed and variable costs of wastewater use, and parts of the operational and maintenance costs of the treatment process is improved. Technology choice is important, particularly in developing countries. Wastewater use, especially in agriculture, can be supported by relatively simple treatment processes of proven technology, with low investment costs and affordable operation and maintenance. Such processes are particularly suited to countries with warm climates, as biological processes perform better at higher temperatures. The investment costs for such simple or 'appropriate' treatment facilities are in the range of 20% to 50% of conventional treatment plants, and more importantly, the operation and maintenance costs are in the range of 5% to 25% of conventional activated sludge treatment plants. These cost differentials are substantial from a financial point of view (Libhaber and Orozco-Jaramillo, 2013). Appropriate technology processes include (but are not limited to) the following: lagoon treatment, upflow anaerobic sludge blanket (UASB) reactors, anaerobic baffled reactors (ABRs), constructed wetlands or stabilization reservoirs for wastewater use. Various combinations of these processes can be set up. In the context of fully exploited freshwater resources, the economic gain from treated wastewater can be significant. The business template developed in Jordan – namely, grant financing coupled with private finance from sponsors under a debt-to-equity ratio of 80:20, and debt finance raised on a limited-recourse basis with shared risks – offers significant potential for the development of much-needed infrastructure projects in developing countries in the future. The additional savings on operational costs through a high level of energy self-supply makes the model even more interesting. There is significant potential for its transfer to similar locations if a donor, such as USAID and MCC in this case, is ready to contribute to the overall costs. MCC expects to adapt the contractual structure developed for the As Samra expansion for use in upcoming infrastructure projects elsewhere in the world, thereby allowing projects that are economically and environmentally beneficial to be implemented and operated by the private sector where such projects would otherwise be unaffordable to the public sector (Keenan and Norman, 2012). The MHI capital investment program makes also reference to a possible third As Samra expansion phase for handling extra amounts of wastewater, budgeted with USD 324million (2020–2024).

Summary assessment – SWOT analysis

The As Samra business case presents a multi-partner model to transform urban wastewater into several benefits for the society. The case required large initial capital investment which was managed through an innovative and multiple award-winning finance model using Viability Gap Funding and risks sharing model. However, the case points asides strength and opportunities also at weaknesses and potential threats for its future and replication (Figure 236).

FIGURE 236. SWOT ANALYSIS OF AS SAMRA BUSINESS CASE

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Strong institutional and regulatory support ▪ High profile partners ▪ Excellent financing package offered by Arab Bank ▪ No foreign exchange risk for Gov. ▪ Innovative business model for infrastructure set up and O&M cost reduction ▪ Financial risk mitigation instruments facilitate multi-party investments ▪ Favorable topography reduces pumping needs while allowing to generate energy	**WEAKNESSES** ▪ Plant of significant size with high O&M needs after BOT hand over ▪ First co-financed BOT and PPP (for public infrastructure) in Jordan; i.e. it cannot build on lessons learnt ▪ A similar favorable topography will be seldom to repeat the energy balance ▪ Cost recovery from tariff system marginal, not to mention farmers ▪ Long-term sludge/slurry disposal ▪ Low job attraction for female workers
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Continuous supply of wastewater and demand for treated water ▪ Virtually zero competition from fresh water due to water scarcity ▪ Stable political environment ▪ Leader in the regional Clean Development Programs ▪ Job creation across sectors ▪ Revision of national reuse guidelines based on WHO (2006)	**THREATS** ▪ Political crisis ▪ Non-compliance with safety plans resulting in human health risks and loss of image/trust/support ▪ Increase in industrial effluent (salinity, metals) ▪ Reuse restrictions

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Case descriptions are based on primary and secondary data provided by case operators, insiders, literature and other stakeholders, and reflect our best knowledge at the time of the assessments 2014/16. Possible errors are solely of the authors, not their resource persons. As business operations are dynamic, data can be subject to change.

Notes

1 Numbers vary between sources, depending e.g. on the inclusion of a Phase I loan.

2 Approximately USD 42 million of the debt package was used to refinance the outstanding loan on Phase 1. All numbers vary to some degree from source to source, also as the bank contribution is in Jordanian Dinar.

3 https://assets.mcc.gov/content/uploads/2017/05/action-2012-002-1136-01-first-major-build-operate-transfer-project.pdf (accessed 6 Nov. 2017).

4 According to MWI (2015) the treatment cost per cubic meter of wastewater in As Samra is USD 0.28 with capital cost and depreciation included. The average treatment costs of other plants are USD 0.76–2.8/m^3.

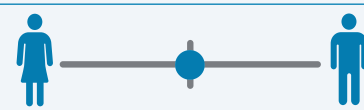
5 http://cdm.unfccc.int/Projects/Validation/DB/DNBGISCCSJ6174719S0D97R4DBWHVS/view.html (accessed 6 Nov. 2017).

BUSINESS MODEL 19

Enabling private sector investment in large scale wastewater treatment

Katharina Felgenhauer

Key characteristics

Model name	Enabling private sector investment in large-scale wastewater treatment
Waste stream	Wastewater treatment for reuse
Value-Added Waste Products	Treated wastewater for irrigation and a healthy environment
Geography	Water-scarce regions
Scale of production	Medium- to very large-scale
Supporting cases in the book	As Samra, Jordan
Objective of entity	Cost-recovery [ ]; For profit [X]; Social/Environmental enterprise [X]
Investment cost range	USD 100–400 million
Organization type	Public-private
Socio-economic impact	High-technology setup and efficient, nearly energy neutral operation of waste-water treatment facility while maintaining affordable tariffs for water users
Gender equity	Socio-economic benefits for male and female population. All users benefit from affordable water tariffs 

Business value chain

Investments which are economically and socially desirable, like large-scale wastewater treatment for reuse, often lack financial viability. The upfront capital investment is too high for public or private sector to assume alone, and long gestation periods and the inability to increase user charges to commercial levels, decrease the likelihood of private sector buy-in. Especially larger plants with significant resource recovery potential often struggle with an appropriate finance plan. To share investment burden, investors are invited to cover the design and construction of the facility, coupled with a time-bound operation agreement, such as the Build-Operate-Transfer (BOT) model applied in the case of As Samra in Jordan. Private sector investment, however, can only be expected if the project is profitable and bankable.

Normally, revenue from such an investment is generated from user fees paid for wastewater treatment, public subsidies and to a minor degree, revenues from water reuse. In some cases, public sector services are configured with fixed or capped end-user fees. This may be useful to ensure broad and inclusive access to the service, such as in the framework of pro-poor policies. If fees are low and

inflexible, the costs for infrastructure installation plus operation and maintenance is hardly recovered fully through user fees, let alone can a profit be made from the operation.

To address this common situation, the business concept applied in As Samra suggests ways to provide an attractive investment opportunity to private sector despite inflexible user fees and high capital costs. Government or donor funds can be used to cover up-front capital expenditure in infrastructure, thereby setting the stage for private investors. Such targeted investment of public sector funds can secure private sector resources in the forms of funding, material assets, technology and management expertise.

Public investment thereby achieves higher impact at a faster and more efficient rate compared to a solely public intervention. After a defined period of operation, the facility can be handed back to government, providing a return in kind on the initial public expenditure. Private sector management ensures a resource-efficient setup and running of the operation, giving the public sector opportunity to continue efficient service provision after the end of the public-private partnership (PPP) agreement. High degrees of energy recovery for system internal reuse is supporting the feasibility of the model.

To achieve this leverage, the upfront investment costs of the overall undertaking must be reduced to a level that makes the venture interesting and viable for private sector investors, including banks. A comprehensive risk management and reassurance scheme has to accompany and guide the partnership to ensure adherence to resource commitment by all parties throughout the duration of the PPP term.

Business model

This business model looks at blended finance options for the up-front investment of medium- to large-scale wastewater treatment plants. The model seeks to attract private sector co-funding and is applicable to situations in which the water user fees cannot fully recover investment, operating and maintenance costs. By reducing the up-front investment needs, the venture becomes financially interesting for private investors.

Public sector funds have to be available for this model to close the funding gap, either through domestic government budget or other sources, e.g. international development partners. Funds should be disbursed as grants to reduce financial liability. These funds are used to cover all or some initial infrastructure investment costs to reduce the up-front investment hurdle (Viability Gap Funding, see Box 10).

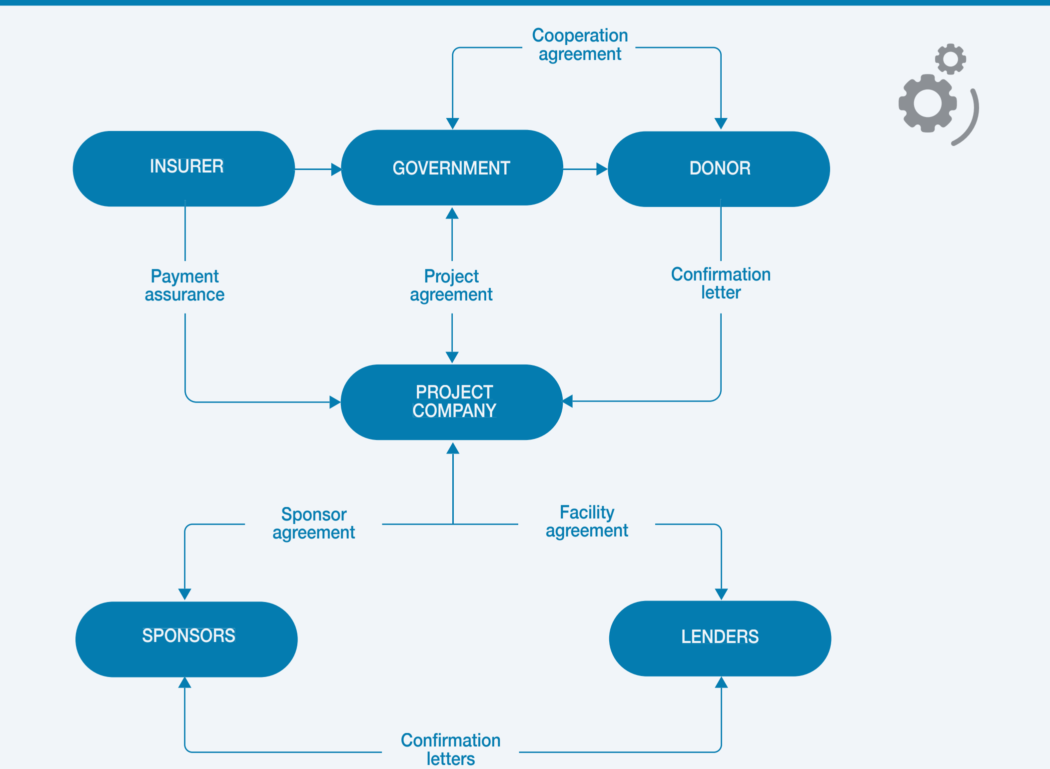
The funds should not subsidize the companies themselves nor their operations but the infrastructure development at hand; companies will earn a return only on their share of investment. Investors can create a project company, in which different sponsors can hold shares, to ease transaction management and tracking. Benefits can be combined with existing measures which attract foreign direct investment, such as tax breaks or reduction of duties and levies.

The private sector co-funding can only be secured if the viability gap funding has been fully committed to. Guarantee mechanisms have to be in place to back the commitments, e.g. through comprehensive contracts (see example in Figure 237) and guarantees from government or multilateral bodies. Backing by the Ministry of Finance (e.g. through a reserve fund) as well as international reinsurance and dispute resolution services help build trust among the partners and lower the investment risk. In the case of As Samra, Jordan, the Multilateral Investment Guarantee Agency (MIGA) provided guarantees against breach of contract for the expansion of the plant and its operation during the 20 year PPP term (MIGA, 2015). Failure to comply with any commitment should lead to strict and clearly spelled out penalties,

Box 10. Viability Gap Funding

Viability Gap Funding (VGF) refers to a grant, one-time or deferred, provided to support infrastructure projects that are **economically justified but fall short of financial viability**. The lack of financial viability usually arises from long gestation periods and the inability to increase user charges to commercial levels, making it unattractive for private sector investments. Viability Gap Funding (VGF) reduces the upfront capital costs of pro-poor private infrastructure investments by providing grant funding at the time of financial close, which can be used during construction. The VGF 'gap' is between the revenues needed to make a project commercially viable and the revenues likely to be generated by user fees paid mostly by poor customers. Although the economic benefits of a private investment project may be high, in situations where the incomes of end users are low, it may not be possible to collect sufficient user fees to cover costs. VGF is designed to make projects that are economically viable over the long term, commercially viable for investors. It helps mobilize private sector investment for development projects, while ensuring that the private sector accepts a share in the risks of infrastructure delivery and operation. Recognized by several international financial organizations the As Samra innovative financing has set up a new template for Viability Gap Financing. This new mechanism provides a significant leverage to the financial assistance of international donors and will allow new projects to materialize.

FIGURE 237. SAMPLE CONTRACTUAL LANDSCAPE BASED ON THE CASE OF THE AS SAMRA PLANT, JORDAN



Source: Adapted from SPC, 2014.

compensation or other rectification measures for all negligent parties. Banks are more likely to avail credit to private sector partners with a substantive risk-sharing mechanism in place.

For such a setup with multiple actors and a high level of interdependency to work, a number of framework conditions need to be fulfilled (OECD, 2014). Government requires strong and stable institutions with growing capacity to manage private sector partners. In Jordan, the Millennium Challenge Corporation (MCC, 2012) funded transaction advisors who would help broker the multi-party agreement system on behalf of the government. Unclear roles and responsibilities, ongoing reforms and policy gaps all contribute to a higher level of uncertainty, i.e. investment risk. The less flexible the water tariffs, the more reliable the government commitment to maintain minimum prices must be. Otherwise, cost recovery risks become difficult for the investor to hedge. Partners need to be aware that negotiations are likely to take considerable time before completion; project implementation will not commence before closure. These transaction costs add to the overall financial burden of the investment opportunity.

Once operational, the treatment plant can generate revenue from government payment or user fees for both, wastewater treatment and reuse of treated wastewater (Figure 238). If government steps in, expenses can partly be recovered through water fees or taxes at household or entity level. Farmers and companies which use treated water can be charged, however, fees will likely remain below the level of fresh water. A differentiated assessment of the clients' willingness and capacity to pay will estimate the cost recovery potential of this revenue stream. Ideally, tariffs should be calculated to cover at least operation and maintenance of the wastewater treatment facility to ensure long-term viability even after the end of the PPP agreement. Flexible tariff structures reduce the economic risk of the investment.

In return, government investment leverages private co-funding for a timely setup and operation of wastewater treatment to benefit large portions of society. Making additional water resources available for use in agriculture and industry supports economic development while maintaining affordable water user tariffs. At the end of the PPP agreement, government will receive the wastewater treatment facility at no additional cost. Efficient management processes will be in place, spurred by private sector interest in efficiency gains during the PPP term.

Alternate scenario

Lower viability gap funding through tender

Difficulties might arise when calculating the dimension of viability gap funding needed to make the venture interesting to private investors. Cost recovery alone will be insufficient to entice investors who are looking to make maximum profit. Investors, for the same reason, are motivated to predict inflated cost estimates when asked for advice in calculating the appropriate viability gap funding.

One way to limit the risk of overspending at the onset is to include the viability gap funding as element in a public tender. Expressions of interest from private sector partners should include an assessment of the amount of grant funding needed. The tender can then be allocated to the best bidder in terms of service provision and viability gap funding necessary to ensure maximum return on the public sector grant. The competitive nature of the bidding process encourages minimum gap funding requests. Service delivery quality, however, should not be compromised.

FIGURE 238. BUSINESS MODEL CANVAS – ENABLING PRIVATE SECTOR INVESTMENT IN WASTEWATER TREATMENT

KEY PARTNERS

- Sector ministry
- Ministry of Finance
- Donor(s)
- Private investor(s) / operator(s)
- Commercial banks
- Risk mitigation broker / insurer

KEY ACTIVITIES

- Secure viability gap funding and revenue guarantee
- Negotiate effective risk management and insurance mechanisms
- Moderate multi-partner platform

KEY RESOURCES

- Grant funding (government or donor funds)
- Budget for payment to operators per m^3 of treated water
- Risk insurance

VALUE PROPOSITIONS

- To create attractive business opportunities for private sector investment in wastewater treatment infrastructure

CUSTOMER RELATIONSHIPS

- Public-private partnership agreement
- Price guarantee
- Risk management and mitigation system

CHANNELS

- Multilateral negotiations
- Mutual risk management guarantees
- Public-private partnership agreement

CUSTOMER SEGMENTS

Private sector with strong track record in wastewater treatment, incl.

- Infrastructure companies
- Operators
- Commercial banks / investors

COST STRUCTURE

- Capital investment (one-time grant)
- Payment to operators per m^3 of treated water (ongoing expenses during PPP term)

REVENUE STREAMS

- Water user fees for wastewater and water reuse
- Government budget allocation and/or donor funds
- High degree of energy recovery as cost saving measure
- P-recovery as cost saving measure and possible revenue

SOCIAL & ENVIRONMENTAL COSTS

- Large-scale treatment plant to occupy land and eco-system
- Sludge storage

SOCIAL & ENVIRONMENTAL BENEFITS

- Business-run operation will generate efficiency gains, i.e. save resources at high output, like low external energy requirements
- Private sector funds increase scope and impact of operation, i.e. more water is treated and available for reuse, reducing e.g. groundwater abstraction

Potential risks and mitigation

This business model has been derived from the successful and acclaimed example of the As Samra Plant in Jordan. In addition to general risks related to reuse projects involving wastewater, such as harm to human and environmental health, the following risk mitigation options are particularly relevant to the financing model at hand.

Market risks: The viability gap funding requires a careful analysis of the business case for wastewater treatment in the region. Without reliable calculations of cost recovery and attractive profit margins, public overspent is likely. The risk can be partly mitigated by including an assessment of necessary viability gap funding in tender selection criteria (see alternate scenario above).

The careful assessment of the business case for wastewater treatment will also help to ensure long-term sustainability of the operation, in particular upon handover of the facility back to government at the end of the PPP. Water users' fees, as sole income to refinance the service, must cover operation and maintenance costs of the facility to avoid continuous subsidy. A differentiated fee structure for users of treated water, e.g. in agriculture or industry, can expedite cost recovery.

Private sector investors will only buy into the venture if viability gap funding is fully committed. A comprehensive risk-sharing and mitigation mechanism has to be negotiated for all parties to agree. This, in return, also provides security to government that public funds will effectively leverage additional investment and result in efficient wastewater service delivery. Sufficient time and resources need to be spent on the partnership negotiations and the establishment of a reliable contractual framework.

Technology performance risks: Leveraging private sector investment supports high-end technology because companies will operate at competitive levels to sustain their own business and generate profit, e.g. through efficiency gains. At the end of the PPP agreement, public sector is likely to receive state-of-the-art facilities. However, private sector partners must be selected competitively, considering track records of service delivery, to avoid technology and funding pitfalls. Quality of service should be guaranteed in unambiguous commitments (contracts) with clear remedy processes in case of non-compliance.

Political and regulatory risks: The model's dependency on reliable funding commitments and risk-sharing entails heightened relevance of political and regulatory stability. Reinsurance guarantees have to be given by stable, legitimate partners that are very likely to remain unchanged throughout the duration of the PPP agreement. A multi-layer support system which includes, for example, national and international partners alike, can be beneficial.

Social equity related risks: The model enables social benefits independent from gender differentiation, such as increased water resources for agricultural and industrial production. Additional jobs will be created at the plant (likely to favour male over female employees) as well as in irrigated agriculture benefitting both gender. The model facilitates the preservation of low water user fees, thus supporting broad and inclusive access to wastewater treatment services across social layers and income groups.

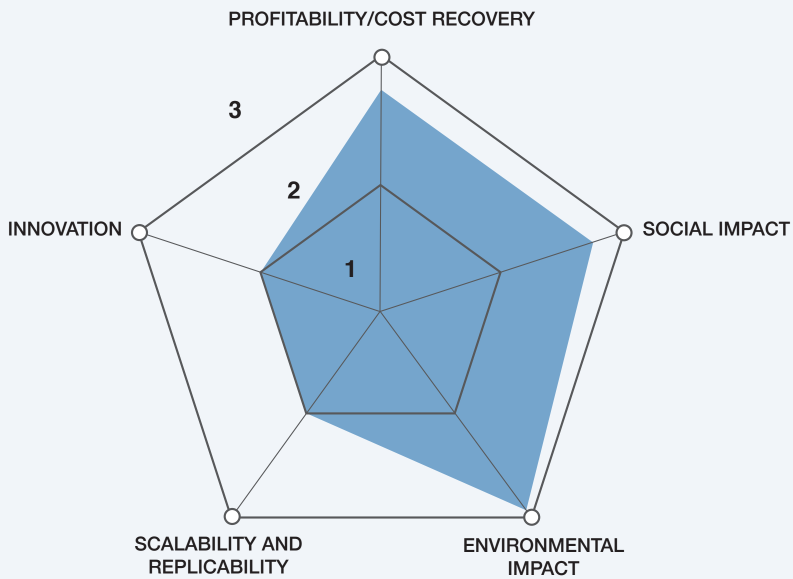
Safety, environmental and health risks: The model is about balancing financial risks for large-scale investments and as such not associated with any technology or particular environmental and health risks. In fact the financial volume is so high that it allows advanced treatment and risk mitigation. Naturally, the construction of a large-scale wastewater treatment plant will impact the site itself and its immediate surroundings, including eco-systems and communities. However, the downstream environmental benefits are significant in terms of preventing pollution, and providing large amounts of reclaimed water. The involvement of private companies in setup and operation of the wastewater treatment plant will support resource-efficient technology and management practices, e.g. covering the energy needs of production from own operation, and phosphorus recovery for reuse. In case of non-compliance with safety measures, potential health hazards will remain possible and demand risk mitigation measures as shown in Table 51 of Business Model 17. However, as this model is about the institutional–financial set-up, independently of the technology, **a separate table on potential risks and risk mitigation has been omitted.**

Business performance

Targeted viability gap funding by public sector helps leap ahead in wastewater treatment and water service delivery. Government and donor grants can leverage funding from private investors while tapping into business technology and expertise in wastewater treatment and management. Overall efficiency gains in water treatment (e.g. via energy recovery) coupled with the provision of additional water resources for agricultural or industrial consumption make the investment model attractive to government. While private sector partners exploit a profitable business opportunity, returns in economic development and environmental protection benefit society at large. Figure 239 shows the ranking of the model with its considerable strength to secure the anticipated positive environmental and social impacts as well as long-term viability.

That being said, the model can be challenging to set up with high transaction costs before operations can begin. Commitments need to be reliably secured through contracts and effective remedy mechanisms. Risk management and mitigation are of great importance, especially in large-scale and long-term ventures, as the model is vulnerable to economic, political and regulatory instability. If the capacity to effectively broker powerful public-private partnerships is further developed, substantial gains can be achieved in public service delivery.

FIGURE 239 RANKING RESULTS FOR BUSINESS MODEL 19



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17. BUSINESS MODELS ON RURAL–URBAN WATER TRADING

Introduction

To sustain increasing urban water demands different strategies are common, such as a combination of long-distance water transfer and advanced wastewater treatment for reuse. Where possible also seawater desalination is being considered. Commonly referenced examples of technical excellence are the production of potable water from wastewater in Singapore and Namibia, based on a business model that is largely depending on reliable technology and positive public perceptions (Lazarova et al., 2013).

In this section, two business models (20 and 21) are presented which use a different approach of exchanging wastewater and freshwater, based on rural-urban water trading. Compared with inter-basin water transfers[1], the here presented models target **inter-sectoral transfers of water** to uses of higher economic value:

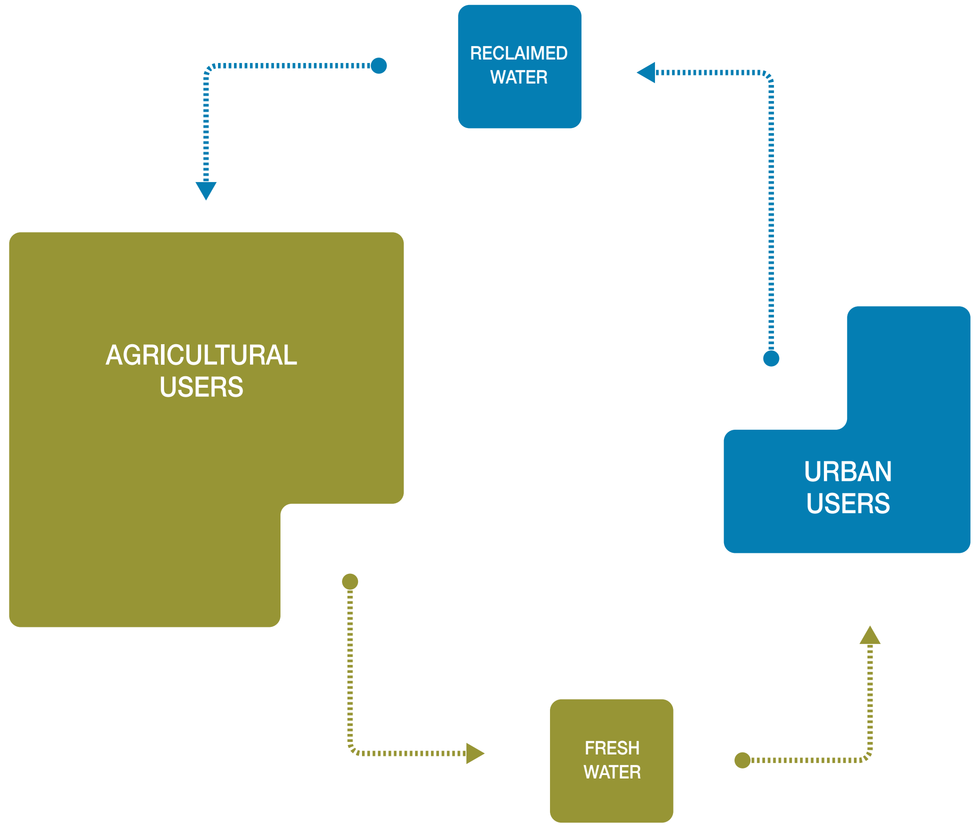
i) Water relocation takes place within the same basin or even the same watershed, moving water originally allocated to agriculture to domestic use, in particular drinking water.
ii) The models involve a two-way flow, i.e. freshwater release and transfer are based on the availability of a return flow of (treated) wastewater able to replace the created water gap and support if needed also other ecosystem service functions.
iii) Aquifer recharge is a common element complementing the available treatment capacity to produce water suitable for agricultural and/or domestic reuse also where treatment capacities are limited.

Given the young age of the presented cases and complexity of their setup, financial performance indicators as well as estimates of the social and/or environmental benefits or costs are largely missing, except for managed aquifer recharge, e.g. in USA or Australia (Maliva, 2014; Megdal et al., 2014; Gao et al., 2014).

Model 20: Inter-sectoral water exchange

Water exchange is driven by social and economic values. Not all uses of water are equally valued. Water for drinking has much high **social value** than for agriculture, yet the quantities involved are smaller. Water for irrigation has a lower **economic value** but the quantities involved are vast; on a global average about 70% of all the world's freshwater withdrawals go towards irrigation. Further, the quality requirements for drinking and agriculture are quite distinct. Therefore, taking a small volume of good quality water away from agriculture could make a sterling contribution to urban drinking water needs, while the resulting reduction to agriculture could be offset by substituting the lost amount with reclaimed water of lower but still appropriate quality, and this independent of seasons, i.e. throughout the year (Figure 240). In instances where farmers can get volumetrically more reclaimed water for irrigation than they release freshwater, and where a water-short municipality gets in a cost-competitive way a reliable supply of quality water for drinking, all partners benefit. Although such water exchange is in theory optimizing the value of the available water within a system, in support of greater environmental sustainability and climate change adaptation, it requires incentive systems and well-formulated contracts to secure the buy-in of a sufficiently large number of farmers who release freshwater for a mutually beneficial and thus sustainable business model. This is no easy endeavour with a range of possible gains but also conflicts (Molle and Berkoff, 2006; GWI, 2010), and might not recover its costs as long as swapped water volumes are low, but will greatly pay off in comparison with the direct and indirect costs of any extended drought period (Martin-Ortega et al., 2012).

FIGURE 240. BASIC IDEA OF AN INTER-SECTORAL WATER EXCHANGE



Source: GWI, 2010, modified

The two case studies, which informed Business Model 20, are from **Iran** and **Spain** and based on the most recent experience with inter-sectoral water exchange. In the case of the Llobregat delta in Spain, a severe drought in 2007–2008 catalyzed significant investments into infrastructure able to produce high-quality reclaimed water to secure farmers' acceptance of a water swap in prolonged periods of drought. For this, the water swap contract remained flexible to allow transfers as needed. In Iran, on the other hand, the urban water deficit of the city of Mashhad is common reality and farmers received incentives to transfer their (entire) freshwater rights to the city in exchange of treated wastewater. Both cases face challenges which provide valuable lessons.

The model offers **several related value propositions**:

- Mitigating drought and related economic costs through reallocating freshwater from agriculture to urban use in exchange for reclaimed water allowing to realign water supply and demand from various sectors based on sector specific water quality requirements.
- Improved crop production and food security across seasons, the support of ecosystem services, aquifer recharge and increased resilience against drought and climate variability.
- Opportunities to raise revenue from sale of freshwater for high-value use and enhancing cost-effectiveness of the overall rural-urban water systems.

Although a water exchange could be approached from the perspective of both main parties, the reality is that in most cases the urban end is the driver of the business. In the case of Iran, for example, an initial survey showed that all city dwellers supported the planned exchange while about 97% of water right holding farmers opposed the plan (Yazdi, 2011). While in this case the political power of the urban sector determined the negotiations, the opposite could be possible, like in the case of Faisalabad, Pakistan (Business Model 23) where farmers strongly prefer (untreated) wastewater instead of (the only temporarily available and nutrient-poor) freshwater.

Model 21: Cities as their own downstream user

The rapid growth in urban population in countries like India is putting immense pressure on urban water supply and wastewater management. This has led to large-scale water transaction between urban and peri-urban areas. On one hand, urban water authorities and informal water traders are increasingly importing water from the urban periphery to meet the urban water need, while on other hand, farmers in the hinterland are using wastewater disposed by urban centers for irrigation (Londhe et al., 2004; Van Rooijen et al., 2005; Jampani et al., 2015; Hanjra et al., 2018). This rural-urban water exchange is a common situation today, and becomes more 'interesting' in water scarce areas, where the imported freshwater is actually the exported wastewater. Model 21 thus brings a developing country perspective to what is commonly referred to as managed aquifer recharge (MAR), looking at the increasingly common phenomenon of a closed water loop where the city is tapping into its own return flow. Aquifer recharge happens in this context on a trajectory from unplanned to planned, with limited wastewater treatment and differently developed formal and informal water markets closing the loop (Foster et al., 2010; Londhe et al., 2004; Jiménez, 2014). This makes the models rather complex and unsafe in contrast to the more commonly described experiences from Australia or USA (Dillon, 2009; Megdal et al., 2014) where in part dedicated agencies manage the underground water banking program under well-defined regulations and monitoring.

The chosen examples in this book are thus not success stories per se (Lazarova et al., 2013) with already documented, positive benefit cost ratio (e.g. Vanderzalm et al., 2015; Perrone and Merri Rohde, 2016), but reflecting situations and challenges observed on the trajectory to a more planned and managed RRR program, which have a significant potential for upscaling, if appropriately addressed.

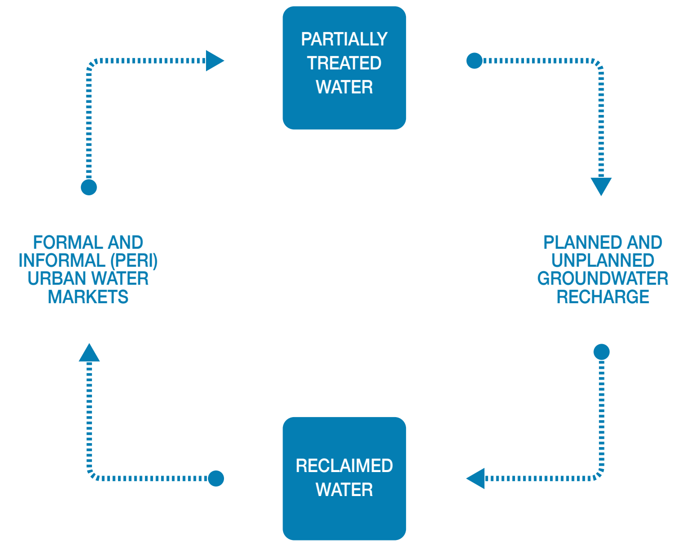
Common related challenges in developing countries are weak institutional linkages for integrated surface and groundwater management across rural-urban borders, as well as missing regulations and monitoring of water quality (Bahri, 2012; Foster and Vairavamoorthy, 2013; Yuan et al., 2016). Without enabling environment, related business models struggle although the economic benefits appear worth the investment. The two cases, which informed Model 21, are from **Mexico** and **India**. In the example from Bangalore, India, largely untreated wastewater is transferred out of town to replenish peri-urban water tanks (reservoirs) and aquifers with multiple benefits for society, farming and ecosystem services. Some of the water returns through informal water markets back to the city, often at prices unaffordable for poorer households. Such rural–urban water transactions are increasingly common around Bangalore and many other cities in India, and need much stronger official acknowledgement to address likely externalities (Londhe et al., 2004).

The second case is the Mezquital Valley of Mexico, which is well-known for its enormous scale of wastewater reuse (Jiménez, 2009). With the recent inauguration of the Atotonilco treatment plant, the recovery of 'freshwater' from the replenished aquifer can become for Mexico City an increasingly important business model with lower pumping costs than any alternative option. The two business cases offer:

- Turning wastewater into a commodity for all-year irrigation and potable reuse through tank revival and/or groundwater recharge.
- Savings in land, disposal and treatment costs while supporting the delivery of ecosystem services.

The resulting water loop from both cases appears to reflect an increasing reality of the circular economy between urban and rural areas, where the urban hinterland functions as a **'kidney'** for urban water reuse (Figure 241).

FIGURE 241. THE EMERGING PICTURE OF URBAN-RURAL-URBAN WATER TRANSFERS



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Note

1 Inter-basin water transfer schemes attempt to reduce regional imbalance in the availability of water, in particular for agricultural or domestic use, by constructing elaborate canals and pipelines over long distances to convey surplus water from one river basin to another which shows a water deficit.

CASE

Fixed wastewater-freshwater swap (Mashhad Plain, Iran)

George K. Danso, Munir A. Hanjra and Pay Drechsel

Supporting case for Business Model 20	
Location:	Mashhad plain/city, Iran
Waste input type:	Treated wastewater
Value offer:	Treated wastewater for farmers in exchange for freshwater for urban use
Organization type:	Public and private (farmer associations)
Status of organization:	Operational (since 2005–2008)
Scale of businesses:	Medium
Major partners:	Khorasan Razavi Regional Water Company, Regional Agricultural Authority, farmer associations downstream of the Kardeh and Torogh dams

Executive summary

This is an inter-sectoral business case whereby treated wastewater from Mashhad city is exchanged for freshwater from farmers in Mashhad plain, Iran. In this business case, the regional water company negotiated the exchange of freshwater rights from farmer associations against access to treated wastewater. The main objective is to mitigate the impact of water scarcity in the urban area and to improve farmers' continuous access to water, also in view of the declining groundwater table in the Mashhad plain. The exchange of reclaimed water against reservoir water rights is one of two parts of a larger water swap project. It involves a number of villages downstream of two dams with the aim of exchanging annually fixed volumes of water: 15.7 and 9.4 million cubic meters (MCM) of treated wastewater for 13 and 7.8 MCM water rights from the Kardeh and Torogh dams, respectively. The project started in 2005 to 2008, and successfully replaced with treated wastewater the fresh water relocation to the city. In the other part of the exchange program, 192 MCM of wastewater are planned to replace farmers' rights to withdraw groundwater and to replenish the declining groundwater table. This part of the exchange was in late 2016, while studying the case, still work in progress.

Farmers' cooperation was facilitated by providing 1.2 times more replacement water than what was withdrawn. In contrast to the Spanish exchange model described in this book, the water volumes were defined and fixed. Major still ongoing challenges relate to wastewater treatment and low effluent quality which does not correspond with local standards and farmers' risk management capacity.

KEY INDICATORS (AS OF 2011)						
Land use	Up to 3,000 ha under irrigation					
Water use:	About 25 MCM treated effluent used for irrigation (15.7 MCM for Kardeh area)					
Capital investment:	USD 6 million (Kardeh dam area only)					
Labor:	-					
O&M cost:	USD 650,000 (Kardeh dam area only)					
Output:	Release of ca. 21 MCM of freshwater for municipal use (13 MCM from Kardeh area)					
Potential social and/ or environmental impact:	Cost savings in water extraction, improvements in living standard and economic development (incl. tourism) because of additional freshwater for Mashhad, reduced overexploitation of aquifers, rivers and lakes. Benefits for ecosystem services.					
Financial indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Iran is a country facing significant water related challenges. The Mashhad plain in the Northeast of the country is a sub-basin of Kashafrud catchment and an example of a region with extended and increasing water crisis. While all surface water resources have been allocated, the only buffer for increasing demands has been groundwater. However, the groundwater table is declining rapidly (about 1.2m/yr) with an annual groundwater deficit of about 200 MCM in the Kashafrud basin. This development is strongly linked to increasing agricultural water needs to match the growing demands from the city of Mashhad. Mashhad is the second most populous city in Iran, with today about 3 million capita, and capital of Razavi Khorasan Province. Every year, about 30 million tourists and pilgrims visit the city for the Imam Reza shrine, which multiply urban food and water needs.

The Mashhad plain has a semi-arid climate with about 250mm of precipitation per year, mostly between December and May. In an attempt to rectify these interlinked issues, the city authorities decided to exchange treated wastewater for freshwater rights of farmers. Based on this objective, a total of about 25 MCM of wastewater have been allocated annually to various purposes. There are two sub-projects of the water swap model in Mashhad plain, one targeting surface water, the other groundwater. The first sub-project on surface water targeted two dams and is running since 2005 and 2008, while the groundwater exchange was in Dec. 2016 still work in progress or under reevaluation (Monem, 2013; Nairizi, pers. comm.):

Sub-project 1: Exchange treated effluent with water rights of the farmers from (a) 15 villages downstream of the Kardeh dam, (b) several villages downstream of the Torogh dam.

Sub-project 2: Exchange of treated wastewater with the right of groundwater exploitation from (a) the wells in the west of Mashhad, (b) the agricultural lands (sample farms) of the Astan Quds Razavi which owns the majority of the arable land in Khorasan Province.

The plan for the second sub-project was that a part of the groundwater will be supplied to meet Mashhad drinking needs and a part will remain in the aquifer to stabilize the groundwater table. Mashhad City's estimated water supply in 2016 of nearly 350 MCM would depend without water swap to over 90% on groundwater.

Market environment

Mashhad, like any other city in the Middle East, has been confronted with several challenges over the years. Most notable one being the explosive population growth and annual tourist inflow and related

food demand making irrigated food production essential for urban food supply. The most common types of crops are cereals (55%), vegetables (21%), orchards (19%) and industrial crops (5%). The bulk of available water (77%) is allocated to agriculture. Substitution of the treated wastewater for farmers' right to use water from the reservoirs and allocation of the reservoir water to the citizens helps to assure water availability to the city with less impact on groundwater resources, while providing a reliable water source for farmer. In a study prior to the exchange, the large majority of the farmers who are water-right holders opposed the swap, while the urban stakeholders unanimously welcomed it (Yazdi, 2011). Aside possible quality concerns, farmers expressed lack of trust in governmental promises regarding water quantities and timing, a lesson learnt from what was promised by the construction of the local dams.

Macro-economic environment

Among the recent decisions taken by Iran's Expediency Council were the adoption and implementation of general plans for recycling water nationwide. The proposed policies and strategies flag prominently that to guarantee future urban water demands, agricultural water rights should be switched from the use of freshwater (from rivers, springs, wells, etc.) to treated effluents. According to Tajrishy (2011), about one-third of the municipal wastewater generated in Iran gets collected, of which 70% gets treated. Forty percent of the treated municipal wastewater (or ca. 10% of the generated wastewater) is already formally reused. A much larger share of (mostly untreated) wastewater is indirectly reused after entering freshwater bodies.

Another pillar of Iran's water resources policy is to improve water productivity by increasing water use efficiency, control the overexploitation of groundwater and avoid the use of high quality urban water for irrigating green spaces, and instead use low quality water for this purpose. Finally, the government also plans to cut off water supply to industries, which do not take practical measures for treating and reusing their wastewater. These government policies provide the legal support for reuse of wastewater for irrigation in Mashhad plain with the aim of improving the environment.

Business model

Like in other inter-sectorial water swaps, the larger economic and social benefits constitute also in this case the main objective. In Mashhad city, a part of the generated wastewater is collected, and treated, and so far released into the next stream. Transferring this water further to support villages downstream of two freshwater dams requires limited extra investments. The reclaimed water is replacing freshwater farmers are entitled to from the water reservoirs. To facilitate this exchange, a contract was signed between farmer associations and the regional water company. While the urban sector gets high quality freshwater from the reservoirs for high-value use, farmers in the two regions receive nutrient-rich reclaimed water at a 20% higher volumetric allocation than their original water entitlement supports. This was an important incentive for closing the contracts (Figure 242).

The other parts of the water swap which targets groundwater would add a significant benefit for the overall ecosystem as the majority of the reclaimed water would be used for aquifer recharge, not 1:1 exchange. This part is still work in progress and will hopefully have an appropriate water quality monitoring mechanism in place.

Before implementing the surface water swap, wastewater user associations were formed. This strategy enhanced cooperation and facilitated the contracting, especially as most farmers did not agree with an irrevocable contract, and the contracts eventually signed with farmers were in two categories (Yazdi, 2011):

A) Contracts between the Regional Water Company and representatives of the association of water right owners from a village based on the total water right of the village.

FIGURE 242. WATER EXCHANGE BUSINESS CASE IN MASHHAD, IRAN

KEY PARTNERS (cum customers in a swap model)

- Khorasan Regional Water Authority/ Company
- Wastewater user association
- Larger farmers
- Khorasan Regional Agricultural Authority

KEY ACTIVITIES

- Establish wastewater reuse associations
- Negotiations for water rights
- Treat wastewater and distribute to farmers
- Chanel freshwater from dams to urban users
- Communication and awareness raising

KEY RESOURCES

- Financial resources
- Legal and institutional framework
- Water rights and rights exchange agreements
- Wastewater treatment facilities

VALUE PROPOSITIONS

- Mitigating drought through reallocating freshwater from agriculture to urban use in exchange for reclaimed water

CUSTOMER RELATIONSHIPS

- Formal contracts between water company and farmers associations or larger individual farmers
- Automated services for urban households

CHANNELS

- Water distribution canals
- Piped household water supply and automated billing

CUSTOMER SEGMENTS (cum partners in a swap model)

- Khorasan Regional Water Authority/ Company
- Wastewater user association
- Larger farmers
- Indirectly: Urban water users

COST STRUCTURE

- Investment cost in wastewater conveyance/distribution
- Operational cost (mostly wastewater pumping)
- Cost of awareness creation and farmer safety training (so far this cost item is underdeveloped)

REVENUE STREAMS

- Urban households, industry paying for freshwater
- Water usage fee paid by farmers (if accepted)
- Indirect (reduced groundwater pumping costs)
- Indirect and direct cost savings from avoided inability to supply enough water to the city of Mashhad

SOCIAL & ENVIRONMENTAL COSTS

- Ongoing challenge to meet the legal requirements for reclaimed water quality and application, leading potentially to costs related to health impacts on farmers and consumers, and groundwater and soil contamination

SOCIAL & ENVIRONMENTAL BENEFITS

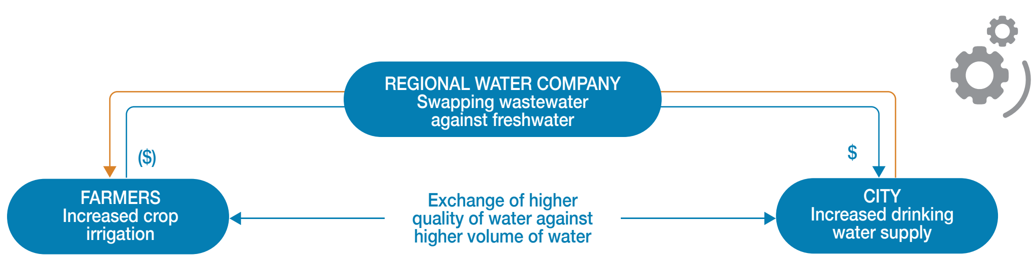
- Preventing agriculture production losses inflicted due to drought, and related social and economic benefits
- City's larger benefits (domestic and industrial growth)
- Improved ecosystem services once aquifer recharge takes off

B) Individual contracts between the Regional Water Company and the (larger) individual water right owner based on the right of every single water user.

Value chain and position

The water exchange in Mashhad supports the agricultural and urban value chains. Although there is no direct monetary exchange between the parties, there are environmental and social benefits associated with this business case for both sides. The actual exchange is of a higher water quantity against a higher water quality than what is available without swap (Yazdi, 2011). As arable land is not a limiting factor, in contrast to water, there will be an increase in cropping supporting the related industry. The city authorities, on the other hand, obtain freshwater and supply it to the urban dwellers to fulfill their mandate. The gains cover the costs of pumping the treated wastewater to the farms while wastewater treatment is anyway taking place, with or without swap. The strength of the business case is the possibility of a win-win situation, if the water quality matches the expectations at both ends. The authorities have the opportunity to sell the released water to households and industries at an affordable price, thus increasing their water sales revenue. So far, water quality delivered to farmers only partially matched national reuse standards and water quality adjustments have been demanded. Figure 243 illustrates the basics of the water exchange used by the business to generate value for all.

FIGURE 243. WATER SWAP MODEL IN MASHHAD PLAIN, IRAN



Institutional environment

According to national law all water bodies (rivers, lakes, aquifers) are public property and the government is responsible for their management. Allocating and issuing permits to use the water for domestic, agricultural and industrial purposes is the responsibility of the Ministry of Energy (MOE) which supervises the construction of large hydraulic works, including dams and primary and secondary irrigation and drainage canals. Within the MOE, the Water Affairs Department (WAD) is responsible for overseeing the development and management of water resources via the Water Resources Management Company (WRMC), provincial Water Authorities/Companies and provincial Water and Wastewater Engineering Companies (WWEC). They are supported by the National Water and Wastewater Engineering Company (NWWEC) which provides oversight and assistance to service providers.

Other direct and indirect stakeholders are the Ministry of Jahad-e-Agriculture (MOA), the Environmental Protection Organization, the Department of the Environment, as well as the National Economic Council and the Supreme Council for Environmental Protection. The amendment of wastewater effluent standards was published in 1994, and in 2010 the national guidelines for use of reclaimed water were published (IVPSPS, 2010; Tajrishy, 2011).

As the provincial Water Authorities now act like companies, water swap contracts were signed in most cases between district branches of the Khorasan Razavi Water Company (like the Mashahad water company) and the farmer associations, in part also with individual farmers irrigating larger land. The regional agricultural authority supported the cooperation with training and capacity development. The Khorasan Regional Water Authority is responsible for the quality of the treated wastewater, and the farmer cooperative handles water right compensation and collection of wastewater distribution revenue and transfers to the Regional Water Authority.

Technology and processes

The largest volume of wastewater comes from domestic sources. For the support of the water swap, the Olang and Parkandabad wastewater treatment plants (stabilization pond systems with anaerobic, facultative and in part maturation ponds) were constructed/adjusted along with distribution networks to transfer the treated wastewater to the farmers' fields. The transfer started operations in 2006 (Parkandabad) and 2008 (Olang). The Olang system receives sewage from east of Mashhad where most of the city hotels and commercial centers are located, while the amount of industrial flow coming to the system is negligible. The Parkandabad plant receives a combined domestic/industrial inflow and like the Olang plant is running over capacity and in need of a significant upgrade. Due to financial constraints both, the treated quantity and effluent quality remain therefore under discussion. The treated wastewater is pumped uplands to the agricultural fields, while the reservoir water is now channeled to the city, no longer to farmers. Treatment capacity upgrades would not only serve sanitation and public health but also farmers who are asking for more reclaimed water given dwindling groundwater reserves.

Funding and financial outlook

A cost analysis of the water swap was attempted for the villages at the Kardeh dam based on 2005–2006 prices when the transfer started. As the wastewater treatment is an independent investment in public sanitation, the major additional costs of the water exchange relate to water conveyance and pumping. The costs were evaluated based on the contract price adjusted to 2005–2006, using a 7% interest rate and 0.5% of the investment towards operation and maintenance costs for power transmission lines. The pump stations and treatment plants operation and maintenance costs are assumed at 2% of total investment. The total volume of reclaimed water exchanged in this sub-project is about 15 MCM per year. The estimated capital cost for conveyance pipelines, pump and power stations were in 2005–2006 about USD 6 million and annual O&M costs (mostly electricity) of around USD 650,000. Direct revenues accrue from farmers and urban water users. However, due to low tariffs and low bill collection, the water service providers do not recover their operation and maintenance costs. The same applies to the running costs of the wastewater transfer as farmers pay very little for the water they are receiving (1 to 3% of the produced crop value), which undermines efforts to increase water productivity and irrigation efficiency. Although water prices have gone up from time to time during recent decades, they have never risen as fast as the prices received for agricultural commodities. Using wastewater, farmers in the Kardeh area reported wheat, maize and barley yield increases by 20–30% and 50–68% for hay production for livestock feeding. Yields of leafy vegetable (lettuce) increased even more (82%) but also soil and crop contamination (Monem, 2013). The water company has as additional benefit savings on groundwater pumping based on the increased access to upstream surface water.

Socio-economic, health and environmental impact

Although farmers were initially skeptical about the transfer, mistrusting the regional water authority based on their past promises on allocation of reservoir water, the formation of associations for risk sharing and possibility to revoke the contracts if parties fail to deliver on their promises, facilitated

their buy-in. The hierarchic institutional setup will have contributed, too. The formation of associations also had advantages for the water company. There were about 920 water right owners in the two sub-project areas although entitlements were not always clear (Alaei, 2011). The formation of associations significantly reduced the contractual transaction costs. As reported in December 2016, farmers appear satisfied with the model and are asking for more reclaimed water, especially as groundwater reserves continue to decline. Farmers also appeared more 'incentivized' to undertake water conservation practices.

Care has to be taken that any change in water flows and directions will not affect other water users and environmental flow requirements. Then the project has the potential to contribute significant aggregate economic benefits that could accrue in particular to municipal households and industry in terms of securing additional freshwater at an affordable price. If the additionally planned aquifer recharge-cum-wastewater/groundwater swap could be realized, also ecosystem services depending on the aquifer would gain. However, the transfer can only become a sustainable success if wastewater treatment capacities are increased and farmers (and potentially the aquifer) receives well treated wastewater. At the current stage, especially leafy vegetables like lettuce showed non-acceptable pathogen levels and also soils are affected. Without close monitoring and implemented risk reduction measures, farmers and consumer are at risk. Several stakeholders expressed concern that training for farmers in support of risk awareness and risk mitigation is missing, while facilities could adopt the WHO (2015) Sanitation Safety Planning which is operationalizing the WHO (2006) wastewater reuse guidelines. Authorities are well aware of the challenges and the Government of the Kashafrud basin has, for example, guaranteed a loan for vegetable farmers who like to shift to non-fruit trees instead of vegetables. The authorities also promised further supports in order to find a market for tree based products which might however be difficult, less profitable and for sure not providing returns on investment as fast as vegetables. Thus more thoughts and initiatives are needed. This also applies to those vegetable farmers in the suburbs of Mashhad who use untreated wastewater.

Scalability and replicability considerations

The water swap represents as a social business model an innovative approach of mitigating the impact of water scarcity, trading water between low and high value users in the society. The key drivers for the documented success of the business were the political will to:

- Address the growing water demands on surface and groundwater resources in an integrated way.
- Decrease high value water losses and inefficiencies in the agricultural sector.
- Consider reclaimed water as far as possible.
- Engage with farmers to work on a mutually acceptable solution.

It is possible to scale as well as to transfer this business case to other geographical areas with similar challenges and institutional set up. However, safety issues, capacity development in risk mitigation as well as issues around well-defined water rights, appropriate compensation schemes for water right holders, proper training and effective institutional coordination have to be fully addressed.

Summary assessment – SWOT analysis

The case presents a rural–urban water exchange (reallocation) to better support high value water needs of the booming city of Mashhad. The project offers interesting lessons on the need to provide farmers with incentives, in particular in comparison with the voluntary water swap in the Llobregat delta of Spain. Farmers' agreement to exchange their fresh water rights against reclaimed water allowed the Iranian water company to use the additional freshwater for domestic purposes while farmers gained additional volumes for increasing their crop production. In an apparent win-win situation, farmers in the Mashhad plain are asking today for even more reclaimed water, catalyzed by dwindling groundwater

resources and drought. While in Mashhad the existing wastewater treatment capacity has reached its limit, the reuse-directed extra treatment facilities in the Llobregat case continue to run below capacity, as long as the Spanish farmers can access any alternative water source.

The SWOT analysis for water exchange in Mashhad plain is presented in Figure 244. The major strength of this business case is that farmers, regional water and agricultural authorities were involved in the negotiations from the start of the project. Farmers were given the needed recognition and incentives as the more obvious advantages of the water swap are at the urban end. While the model appears like a win-win for all parties, the economic benefits have not been quantified. This could however help the argumentation for further investments, e.g. in treatment capacity.

The challenges of the case are the cost of wastewater supply to the farmers, low cost recovery and the low treatment capacity within the city resulting in the release of reclaimed water for irrigation of in part low quality. Aside treatment upgrades, capacity development of farmers on possible risks and options for the safe use of wastewater have been strongly recommended.

FIGURE 244. SWOT ANALYSIS FOR MASHHAD PLAIN, IRAN

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Incentivized agreement with farmers via associations which reduces transaction costs ▪ Win-win situation for city and farmers ▪ Model can be up-scaled and repeated ▪ Economic benefits likely high but so far not quantified	**WEAKNESSES** ▪ Gaps in water quality monitoring and insufficient wastewater treatment ▪ The cost of conveying treated water to farmers ▪ Low education of farmers on waste water use and water conservation ▪ Water rights partly unclear as some official title holders left the region
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Strong governmental support of water reuse and water swaps with surface and groundwater ▪ Potential for aquifer recharge ▪ Sufficient arable land for irrigation and increasing wastewater volumes	**THREATS** ▪ Sustainability of the project without further investments in wastewater quality ▪ Farmers perception on the use of treated wastewater could change if water of inferior quality is delivered ▪ Public acceptability of wastewater for irrigation could change if potential risks are not controlled ▪ The swap does not stop informal wastewater reuse and risk of epidemics which could also affect the exchange

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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2013–2016. As business operations are dynamic data can be subject to change.

CASE

Flexible wastewater-freshwater swap (Llobregat delta, Spain)

Pay Drechsel, George K. Danso and Munir A. Hanjra

Supporting case for Business Model 20	
Location:	Llobregat delta, Barcelona, Spain
Waste input type:	Treated wastewater
Value offer:	Treated wastewater for farmers to release in times of drought freshwater for domestic (and industrial) purposes
Organization type:	Public and private
Status of organization:	El Prat WWTP operational since 2004, with several upgrades since then; Sant Feliu WWTP operational since 2010
Scale of businesses:	Medium
Major partners:	Farmers, Catalonian Water Agency (ACA), City of Barcelona, European Union (EU)

Executive summary

This business case presents an example of integrated water resources management (IWRM) in support of a voluntary water exchange between local farmers and the Catalonian Water Agency (ACA) in the Llobregate River basin delta. The inter-sectoral water transfer builds on a flexible approach which allows negotiation between the parties involved to adapt to the intensity of seasonal drought and priority water needs. In this European Union co-funded project, the ACA treats urban wastewater to different, reuse defined levels. The main clients are farmers who are obliged to stop using surface water in times of drought. In exchange for accepting treated wastewater the city obtains the protected freshwater for aquifer recharge. This is in large a social responsibility business model, which allows on one hand (i) ACA to deliver on its water supply mandate also in times of extreme water shortage; and on the other hand (ii) gives farmers a reliable water supply to cope with drought or to go beyond (low revenue) rainfed farming; while (iii) the city gains in terms of drinking water, environmental health, aquifer protection and more resilient short food supply chains. From an economic perspective, the investment costs are marginal compared to the direct and indirect costs of a severe drought as experienced in 2007–2008 (Martin-Ortega et al., 2012). The case also realizes an often demanded paradigm shift where the degree of water treatment and allocation differ between types of reuse to optimize the overall returns on investment.

COMBINED KEY INDICATORS FOR THE EL PRAT AND SANT FELIU WWTPS (2012)						
Land use:	1076 ha (maximum irrigation area potentially served)					
Wastewater treated:	Up to 146MCM per year with about 20MCM for agriculture (water swap)					
Capital investment:	EUR 15.12 million (treatment upgrades)					
O&M:	EUR 3.11 million per year (treatment); EUR 2.56 million per year (water conveyance)					
Output:	Among others, the possible release of up to 20MCM freshwater per year					
Potential social and/or environmental impact:	Improvements in economic development because of additional freshwater, for domestic use and environmental flow, and reduced overexploitation and protection of the local aquifer.					
Financial indicators (for both plants assuming annual water swaps; FAO 2010):	Payback period:	Depending on the volumes actually reused/ swapped	Net Present Value	70–115 million Euro	Benefit-cost ratio:	3–5 to 1

Context and background

Eastern Spain has been experiencing severe droughts in its recent past and is expected to experience even more in the coming years. To support Barcelona, the government is using multiple strategies, including long distance transfer and seawater desalination. Another measure to reduce the water deficit is reallocation matching water needs and water quality. Reuse of treated wastewater is part of this approach. Already today, about 13% of Spain's total wastewater volume is reused, which is far above the European average[1]. The Lloberegat delta region presents an example of Spain's reuse efforts applying an IWRM approach to deal with the complexity of surface and groundwater resources under stress within a basin cutting across rural and urban boundaries. This stress has qualitative and quantitative dimensions. By the end of the 1980s, the Llobregat River, which runs through parts of Barcelona was one of the most degraded rivers in Western Europe, putting increasing pressure on water users and the aquifer (Sabater et al., 2012). Supported by the 1991 European directive on urban wastewater treatment, a comprehensive rehabilitation programme has been implemented along the river allowing the situation to improve dramatically.

The Llobregat River's lower valley and delta, located in Barcelona's province, consist of about 30 km^2 of alluvial valley, up to 1 km wide, and a delta of 80 km^2. In spite of the delta's very close proximity to the city, it constitutes a wetland of international importance for wildlife, especially migrating birds. Its fertile farmland supports intensive agriculture (fruits, vegetables) for the urban market, and as a protected green belt, the delta helps restricting urban sprawl. The delta aquifer is one of the most important fresh water resources of the Barcelona area, forming an underground source with a capacity of 100 million cubic meters (MCM) of water,[2] which is however under pressure from seawater intrusion. With an average annual precipitation in the Lloberegat delta around 620mm/yr (2015: only 346mm), spread over two to six rainy days per month, not only the city and local industries but also the delta farmers rely on the aquifer for supplementary irrigation, resulting increasingly in over-exploitation and water salinization. The need to optimize water allocations across sectors was highlighted during the severe drought of 2007–2008 in Northeast Spain, which caused very high societal, economic and environmental cost of an estimated EUR 1605 million (Martin-Ortega et al., 2012). Aside supporting human needs, a significant part of the EU supported effort targeted ecosystem services of the

Llobregat River and delta by reducing water loss to the sea, and pumping it upstream over 15 km to re-support the natural river flow.

Market environment

In a region suffering regularly from very low rainfall, access to water is fundamental to many economic sectors, including agriculture, as well as environmental needs. Based on a participatory stakeholder dialog, the treatment of the wastewater in the Llobregat delta follows a step-wise approach to meet the particular water quality requirement of each reuse purpose, considering that any additional treatment will cost extra and should only be activated on demand. Wastewater leaving the plant for the sea undergoes secondary treatment, while for aquifer recharge tertiary treatment including reverse osmosis can be used, while farmers demanded in addition the demineralization of the reclaimed water as water salinity prevented them from using it. As a result, the two wastewater treatment plants (El Prat and Sant Feliu) in the district of Baix Llobregat were designed to support directly or via water exchange a range of demands (agriculture, environmental flow, wetland ecosystem services, seawater barrier through managed aquifer recharge, urban water supply, recreation and industry) (Table 57).

About 20MCM/year of treated effluent from the two plants could support seasonal irrigation of up to about 1,000 ha (Heinz et al., 2011a, 2011b). As drought conditions vary, the water exchange was set up on voluntary base without specific quantitative targets. In general, most farmers prefer the usually less saline river or groundwater. Only when these sources get scarce, and farmers are no longer allowed to abstract water, reclaimed water was used. The efforts by the authorities to install additional treatment capacity for halving the salinity level of the reclaimed water to about 1.4 millisiemens per centimeter (mS/cm) responded directly to farmers' water quality concerns.

The water exchange can build in this case on an efficient water distribution system, where farmers are in relatively close proximity to the wastewater treatment system and freshwater users, limiting upstream pumping costs of the treated water.

Macro-economic environment

The government of Spain is giving high priority to the improvement of water use efficiency across sectors, especially in the drought affected Eastern region around Barcelona. While different coping strategies are being implemented, inter-sectoral water transfer based on wastewater treatment for reuse was described as the least costly option (EUR 0.34/m^3) compared with desalination of sea water (EUR0.45–1.00/m^3) and water transfer from other areas (EUR 8.38/m^3) (Hernández-Sancho et al., 2011).

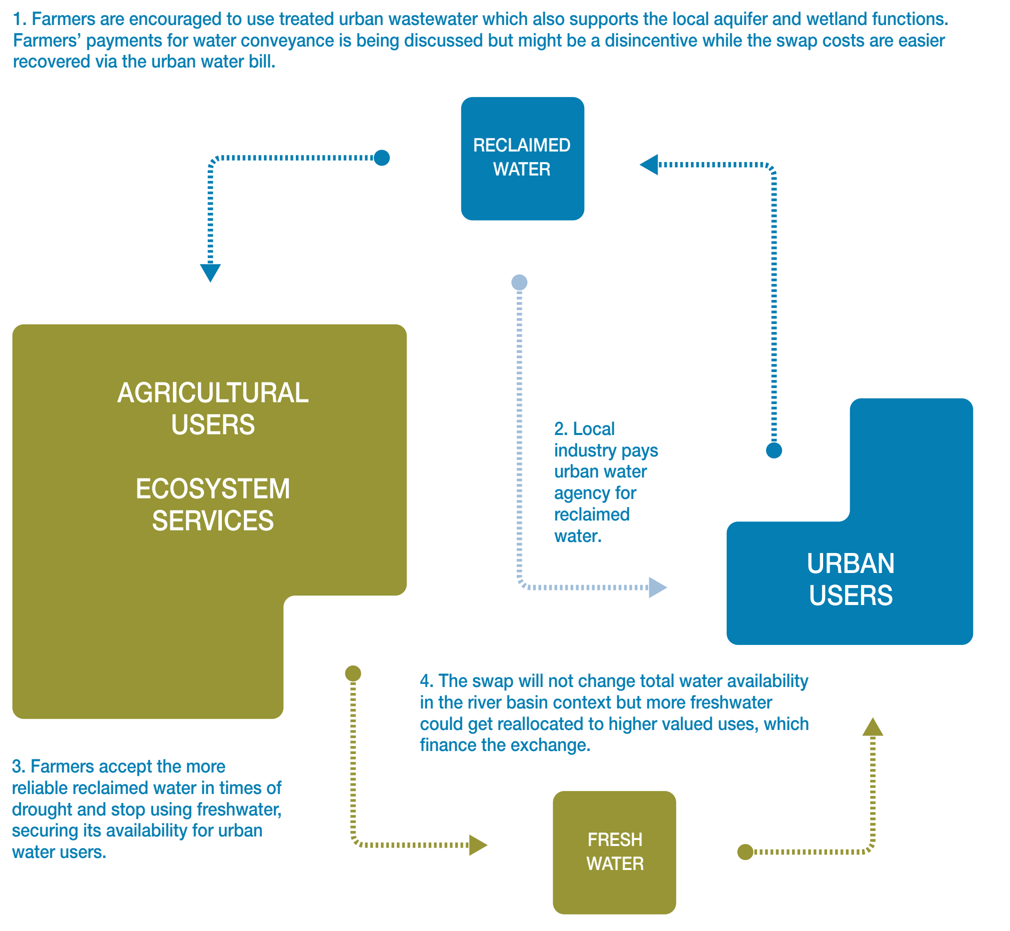
TABLE 57. MULTI-PURPOSE USE POTENTIAL OF RECLAIMED WATER IN THE LLOBREGAT DELTA

	EL PRAT DE LLOBREGAT WWTP (MCM/YR)	SANT FELIU DE LLOBREGAT WWTP (MCM/YR)
Agriculture	13.09	7.36
River stream flow	10.37	–
Wetlands	6.31	–
Seawater barrier	0.91	–
Municipalities	–	0.11
Recreation	–	0.37
Industry	5.48	–
Total	**36.2**	**7.84**

Source: Hernández-Sancho et al., 2011.

To assess the economics of water exchange between farmers (releasing freshwater) and cities (providing reclaimed water) a broader perspective at watershed level is needed. The IWRM concept offers an appropriate framework which allows to consider water-related sectors, services and their interdependencies. The first analysis showed that water reclamation (treatment and conveyance) costs would be more than offset by the value the exchange offers urban water supply, not to mention the direct and indirect costs of the next prolonged drought. The macro-economic benefits will increase with more water transferred to high-value usage. While farmers' financial advantages are limited, the urban water sector is best positioned to absorb the costs for the exchange (Figure 245) unless the investment is considered an insurance against the possibility of significant loss.

FIGURE 245. WATER SWAP MODEL IN THE LLOBREGAT DELTA, SPAIN



Source: Adapted and modified from GWI, 2009.

Business model

The business model offers multiple value propositions through need-based wastewater treatment for different water reuse purposes. Aside the support of ecosystem services, irrigated crop production will be an important water user in periods of drought when farmers are asked to withdraw from

surface water use. Through freshwater savings and additional aquifer recharge, ACA can continue its freshwater supply for the urban population. The volume of the business transaction depends on the duration of the drought and related negotiations between ACA and farmers. While urban users would be the main source of finance for the costs, there will be a range of environmental benefits (Figure 246). While farmers can save in pumping costs and fertilizer application, the benefits for the city are large, and can provide the exchange with a net benefit depending on the traded water volume (see Finances below).

Value chain and position

Table 57 shows the technically possible volumetric benefits of the exchange for different usage of the water released by the two mentioned treatment plants in the Llobregat delta. While the numbers show the potential, the majority of the treated wastewater is used so far to maintain or re-establish the Llobregat River's flow while farmers shifted to treated wastewater so far only in those periods when there was no other (equally reliable) alternative left to maintain crop yields and/or to avoid shifting to low value rain fed crops. The city gains in this situation by securing additional freshwater for domestic and industrial purposes with a higher water value than what it can offer agriculture. While the exchange is so far of voluntary nature, farmers could gain higher bargaining power and opt for a formal exchange of water rights with other buyers once they have better information on the nature of the water market.

Institutional environment

The main stakeholders in the project are farmers, the water company of the metropolitan area of Barcelona, the water administrations (at regional and local level), and the environmental administration. Because the inter-sectoral water transfer relies on farmers and the city, a cooperation and negotiation process between farmers and the water supply company ACA was essential. Being part of the decision-making process, has been described as an important pillar for farmers' support of the model.

The European Water Framework Directive (WFD) and the Catalonian Water Reuse Program were key for the development and financial support of the water swap model, and also the regulations for reuse to be considered.

Since the swap became operational, farmers are making use of the reclaimed water, however, to a smaller extent than what could be made available based on treatment capacity. Farmers view the reclaimed water only as a last resort to be used when freshwater use is no longer permitted, reliable or salinity of the freshwater exceeds the one of the reclaimed water. As each swap is a response to a particular drought, negotiation between farmers and the water administration remain dynamic and prevented so far contractual commitments. To increase farmers' use of reclaimed water also under normal seasonal water stress, there are different instruments and incentives possible which have however to be aligned with farmers water rights (concessions), especially in view of groundwater abstraction.

Technology and processes

By generating a reliable flow of high quality reclaimed water, the options available for integrated water resources management have widely expanded to allow in-stream river water substitution, restoration of natural wetland areas, agricultural irrigation and aquifer recharge to block seawater intrusion. Those management options have been possible thanks to the implementation of an extensive water distribution system that allows distribution of reclaimed water to a point 15 km upstream of the reclamation facility, and to a seawater intrusion barrier within a few kilometers of the plant. The water distribution network has 18.8 km of main pipes.

The wastewater treatment plant of El Prat de Llobregat has been operating since 2004 and has a capacity of up to 420,000m^3/day. It includes an activated sludge treatment process that was upgraded in 2006 to achieve nutrient removal, using biological nitrification-denitrification, plus biological and chemical phosphorus removal. About two-thirds of the secondary treated water is discharged into the Mediterranean Sea, while one-third could undergo depending on demand tertiary treatment for reuse, with a smaller part of it also reverse osmosis (RO). An additional desalination plant which is using membranes for electrodialysis reversal (EDR), is able to produce for farmers up to 57m^3 of improved irrigation water per day (18.8MCM/yr).

FIGURE 246. BUSINESS MODEL CANVAS FOR INTER-SECTORAL WATER EXCHANGE IN SPAIN

KEY PARTNERS (cum customers in a swap model)

- Farmers irrigating in the Llobregat delta willing to accept reclaimed water
- Catalonian Water Agency (ACA)
- Others: EU-WFD

KEY ACTIVITIES

- Treat wastewater to an acceptable level for farmers and wetland
- Make reclaimed water accessible for reuse
- Negotiate water swap with farmers
- Obtain freshwater and sell to households and industries
- Awareness creation for water savings and reuse
- Maintenance of treatment facilities

KEY RESOURCES

- Financial resources for tertiary wastewater treatment and desalination units
- Legal and institutional framework for collaboration
- Awareness campaigns
- Farmers' consent

VALUE PROPOSITIONS

- Mitigating drought (related costs) through reallocating freshwater from agriculture to urban use in exchange for reclaimed water allowing to realign water supply and demand from various sectors based on sector specific water quality requirements

CUSTOMER RELATIONSHIPS

- Negotiations between ACA and farmers considering expected drought duration and sectoral water needs
- ACA services for urban households

CHANNELS

- Roundtables for negotiation
- Distribution canals for irrigation with reclaimed water
- Piped water supply for households and automated billing

CUSTOMER SEGMENTS (cum partners in a swap model)

- Farmers in need of water of acceptable quality
- Catalonian Water Agency (ACA)

Indirectly:

- Urban water users

COST STRUCTURE	REVENUE STREAMS
▪ Investment cost as well as O&M costs unless the swap allows sufficient urban revenues ▪ Water conveyance and distribution cost ▪ Cost of awareness campaigns	▪ Urban households pay ACA for extra (released) freshwater, and farmers for high-value crops ▪ Farmers have been asked to pay for water conveyance (only) ▪ Indirect revenues (cost savings) in view of socio-economic damage during drought from interrupted or reduced water supply
SOCIAL & ENVIRONMENTAL COSTS	**SOCIAL & ENVIRONMENTAL BENEFITS**
▪ Potential health impact on consumers from the consumption of crops irrigated with reclaimed wastewater not meeting all possible risk factors	▪ Avoidance of production losses inflicted due to drought ▪ Urban consumers continue to have fresh fruits and vegetables ▪ Improved water allocations for the Llobregat aquifer, river and wetlands and related ecosystem services ▪ Hydraulic barrier against sea water intrusion

Box 11. Treatment for nature

A third WWTP operates since 2010 on the western edge of the delta at **Gavà-Viladecans** with a capacity of about 23MCM/yr. The treated effluent is sent to the headwaters of the system of canals and corridors feeding into the Murtra lagoon, with the goal of protecting water quality in the nature reserves and preventing eutrophication. One of the lines, which treats 50% of the total flow, has a membrane bioreactor system (MBR). This process gives high quality reclaimed water which can be reused. However, the water is usually not used directly for irrigation, but for stabilizing the hydrological balance and to recharge wetlands.

Funding and financial outlook

The overall project had an initial budget of EUR102 million; 85% of that amount has been covered by European Union Cohesion Funds, through the Spanish Ministry of the Environment, and the remaining 15% has been covered by the Catalan Water Agency. Comparing costs and benefits of the water swap, including discounted capital costs, the projected net profit of water transfer when considering agriculture and the city is around EUR16 million per annum (Table 58), without counting environmental benefits. The water swap could lead to savings as well as gains for farmers and the city. In an ideal situation, the investment of one euro in the use of reclaimed water creates an income increase in agriculture of approximately EUR1.6 (Hernández-Sancho et al., 2011). Farmers face less groundwater and surface water pumping costs as well as costs of fertilizing, while they can maintain high value crops or expand irrigation. The magnitude of the benefits increases with the duration of the swap.

In general, the cost of the additional wastewater treatment is paid by the urban water users and the cost of conveying irrigation water by farmers. However, with the largest share of benefits accruing at the city level, and the fact that the system depends on farmers' voluntary contribution, they would need

TABLE 58. COSTS AND BENEFITS OF WATER REUSE AT THE LLOBREGAT DELTA

CHARACTERISTICS	EL PRAT	SANT FELIU
Irrigated farmland (ha)	801	275
Effluent volume applicable for irrigated agriculture (MCM/yr)	13.0	7.3
ANNUAL COSTS. . .	**MILLION EURO/YR**	**MILLION EURO/YR**
Cost of new treatment units	1.09	0.08
Operation and maintenance cost of treatment	2.6	0.51
Cost of conveying effluents	0.12	0.20
Cost of conveying water released for urban use	1.43	0.81
Total cost of water reuse and exchange (A)	**5.24**	**1.60**
. . . AND ANNUAL BENEFITS		
Value added to agriculture	0.35	0.46
Value of water exchanged for city use	14.43	8.12
Total economic benefit of water reuse and exchange (B)	**14.78**	**8.58**
Total value added of water reuse and exchange (B-A)	**9.54**	**6.98**
UNIT COSTS AND BENEFITS	**EUR/M^3**	**EUR/M^3**
Unit cost of water reuse and exchange	0.40	0.22
Unit total economic benefit for agriculture and city	1.14	1.17
Unit cost/benefit ratio	**2.85**	**5.3**

Source: Heinz et al., 2011a.

to be convinced of the value of the exchange for themselves (reliability of the water supply, savings of pumping, nutrient value) and depending on urban needs be supported by additional incentives to engage in the exchange. If farmers' buy-in can be augmented, the urban benefits could be sufficiently high to carry the exchange, also if farmers do not pay for water conveyance.

It should also be considered that aside the stigma of wastewater use, farmers expressed concerns how the [European] market and legislations would perceive the use of reclaimed water.

Based on the first evaluation (Hernández-Sancho et al., 2011) the water swap model started successfully as farmers accepted the reclaimed water in times of water stress. In the first 1.5 years, 35.5MCM were reused to re-establish the Llobregat River flow, 2.4MCM for agricultural irrigation, 4.8MCM to stabilize wetland ecology and 0.4MCM to reduce salt water intrusion in the aquifer. Since then agricultural reuse (and water release) remained at a similar level although details on actual volumes during the drought of 2012 and 2015–2016 could not be accessed (Santos and Marcos, 2009).

If a sensitivity analysis were to be done, it would show that the overall NPV would be highly sensitive to the size of released water and resulting urban water benefits (FAO, 2010), which were so far much lower due to sufficient precipitation. Urban cost recovery remains also challenged due to low water tariffs combined with difficulties to accurately determine the cost of wholesale water services in a complex situation when the infrastructure is shared among different uses, e.g. regulation and transport of raw water for populations, energy uses and irrigation (García-Rubio et al., 2015).

Socio-economic, health and environmental impact

The anticipated main impact is based on the reduction of the direct and indirect costs of any forthcoming severe drought as in 2007–2008. The exchange of water towards higher value water use

allows economic gains for different sectors without that the overall amount of water is changing. The project appears to succeed because farmers started to use the reclaimed water and freshwater has been released to other sectors, such that the overall availability of water in the metropolitan area of Barcelona has improved. The income of the farmers has increased to some extent and the availability of reclaimed water for irrigation has been improved in times of low freshwater supply.

An interesting side-effect is that water consumption for domestic use has decreased and the water quality of the Llobregat aquifer has improved widely. Although this was not a direct objective of the business case, the water crisis in 2007–2008 and implementation of the inter-sectoral water exchange and related educational efforts increased public awareness for water savings. Energy savings associated with the reduction of pumping groundwater were quantified at around 4m kWh/yr which translates approximately into 1,440t of CO_2 equivalent per year. The use of reclaimed water has also led to cost savings in chemical fertilizers and related energy quantified as 2,170t/yr, including the avoided use of phosphorus (Hernández-Sancho et al., 2011).

Also an improvement in the Delta aquifer for all parameters related to seawater intrusion has been verified (Hernández et al., 2011), and even the wastewater which is with less treatment discarded into the sea, still serves a purpose: brine produced at Barcelona's Desalinization plant (which support 20% of Barcelona with potable water) is blended with treated water from the El Prat WWTP in a ratio lower than 1:1 before it enters the sea.

Scalability and replicability considerations

The key drivers for the success of this business model are common in many water-stressed regions and replicable:

- Water scarcity combined with growing urban water needs made water reclamation and innovative water allocations for reuse important and necessary for the region.
- Early stakeholder consultation leading to the adaptation of treatment quality to farmers' needs and their voluntary acceptance of the seasonal water swap (which can also be key risk factor as long as the exchange remains voluntary).
- Single agency (ACA) with mandate for wastewater treatment and providing drinking water to the city, thus providing greater flexibility and ease for negotiating with farmers on the inter-sectoral water exchange.
- Economic analysis showed an overall positive economic balance, not counting improved ecosystem services.
- Support from the Government of Spain and European Commission to improve inter-sectoral water use efficiency.

Replication of the case is recommended as it represents an interesting example of the often demanded paradigm shift (e.g. Huibers et al., 2010; Murray and Buckley, 2010) where different water uses are matched with their required water quality, which includes that (i) wastewater treatment is designed for the planned type of reuse; and (ii) water is allocated to the type of use which allows the highest returns for the respective water quality. It is also a case where the IWRM framework was successfully applied across sectors including the urban one. However, monitoring crop and water quality will be needed to prevent that produce markets, also in other EU countries may reject crops irrigated with reclaimed water.

For a full success of the swap, the city might prefer to plan with a released minimum water volume, while farmers should not see the reclaimed water as additional water to increase their irrigated area, which would prevent any release of freshwater for the city. GWI (2009) stressed that voluntary water swap

models can be flawed due to the potentially unlimited agricultural water demand and no direct benefit for farmers from the release of their water. Thus the swap needs regulatory support, for example in form of seasonal surface or groundwater abstraction limits (volumes, time periods) which farmers have to adhere to, in exchange of a reliable supply with reclaimed quality water. In the case of the Llobregat delta, extraction from the common irrigation channels by farmers is prohibited in drought periods and, at such times, farmers are obliged to use reclaimed wastewater from the El Prat de Llobregat WWTP. The same applies to the Sant Feliu de Llobregat WWTP where the limit for agricultural use of water from the Llobregat river is 1.5m^3/s, but in periods of water shortage this use is reduced to 0.8m^3/s, and farmers are obliged to use treated wastewater or to switch to less demanding crops (FAO, 2010).

Summary assessment – SWOT analysis

In this case significant investments went into infrastructure able to produce high-quality reclaimed water to secure farmers' acceptance of a water swap in prolonged periods of drought. Thus the water swap contract remained like an insurance policy flexible, given the, in large, unpredictable nature of the extent of a possible drought period and actual need for farmers to seek alternative water sources. Despite harsh conditions in 2007–2008, 2012 and 2015–2016, the installed infrastructure (reverse osmosis, desalination) was so far hardly used for serving agricultural demand. Financial considerations/limitations might have contributed to the underutilization.

FIGURE 247. SPAIN WATER SWAP SWOT ANALYSIS

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Governmental support to invest in infrastructure to mitigate possible risks from climate change ▪ Dialog with farmers and offer of reliable water supply ▪ Flexible targets and execution allow adaptation to extreme climate events and water savings ▪ Multi-purpose reuse program with aligned treatment levels supporting urban and ecosystem needs ▪ High economic benefits for society covering all investment costs	**WEAKNESSES** ▪ The cost of temporarily unused infrastructure (RO, EDR) in times of sufficient freshwater supply ▪ Missing incentive systems for farmers to use reclaimed water more, and more frequently ▪ Water salinity challenge undermining farmers' acceptance ▪ Farmers market reservations related to wastewater use ▪ Limited cost recovery without urban users paying for released water
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Flexibility allows farmers to react to different drought situations, while the option to swap a fixed minimum volume could be an alternative. ▪ Educational options to improve farmers' acceptance of water reuse ▪ Similar locations and challenges exist in various countries for replication of concept and strategy	**THREATS** ▪ Changing public perception on the use of treated wastewater ▪ Financial and economic crisis affecting plant operations ▪ Alternative freshwater sources (desalinization, long-distance transfer) appear more reliable than a voluntary agreement and are already in place or in construction

While farmers prefer to use the aquifer as their main water source, supplemented by the Llobregat River water, they complied with the swap although to a lower extent than anticipated. Without set targets, it is difficult to assess the difference between any intended and actual outcome or to predict if the swap will remain an option of choice once Barcelona can rely on sea water desalinization. This also poses questions how far the presented cost-benefit analysis (e.g. FAO, 2010; Heinz et al., 2011a, 2011b; Hernández-Sancho et al., 2011) for a regular water exchange remains valid. On the other hand, in view of the possible damage an extended drought period could cause, any of the current investments in risk mitigation (water swap, desalination, water transfer) would have significantly higher returns on investments already with the next drought (Martin-Ortega et al., 2012).

Figure 247 presents the SWOT analysis for water exchange in Llobregate. As the success of the water exchange depends mostly on farmers' willingness to accept reclaimed water, while stopping the use of other sources, tax and/or regulatory incentives should be discussed in support of the process. For a detailed risk analysis see FAO (2010).

Contributors

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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014–2016. As drought periods vary in frequency and extent, so will the voluntarily swapped water volumes and related costs and benefits.

Notes

1 http://ec.europa.eu/environment/water/reuse.htm (accessed 4 Nov. 2017).

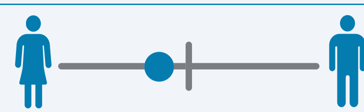
2 http://geographyfieldwork.com/LlobregatWaterReclamation.htm (accessed 4 Nov. 2017).

BUSINESS MODEL 20

Inter-sectoral water exchange

Pay Drechsel and Munir Hanjra

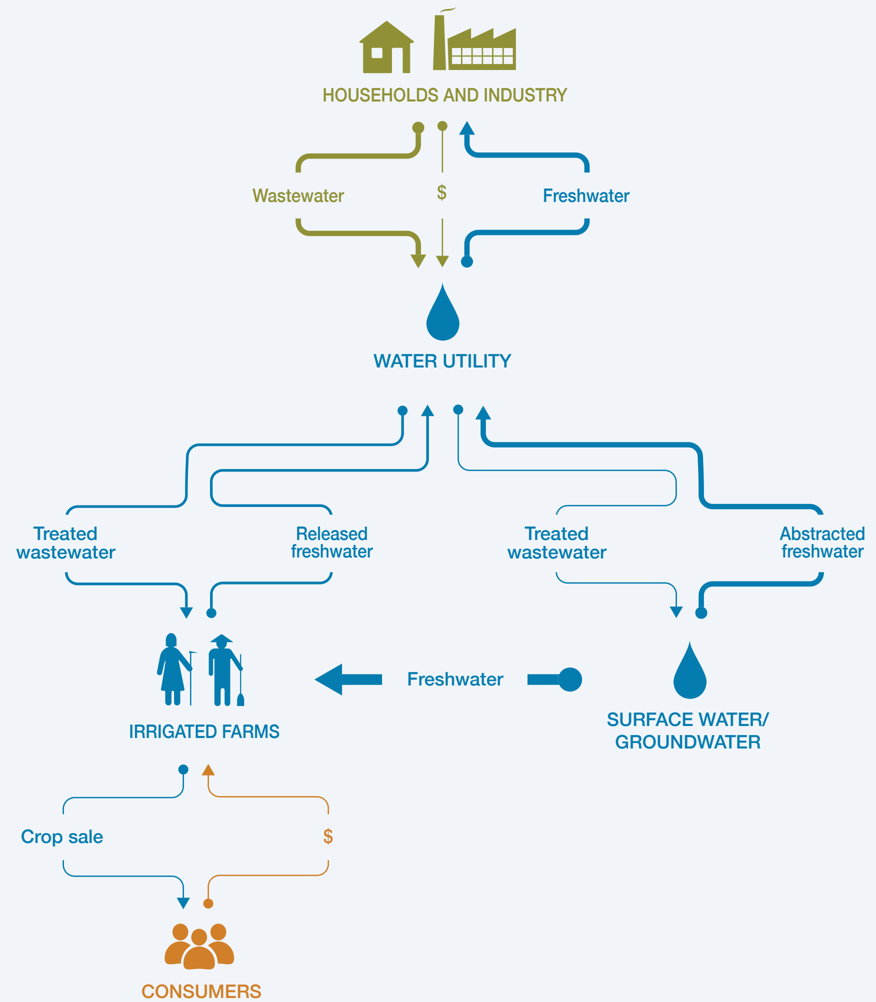
Key characteristics

Model name	Inter-sectoral water exchange
Waste stream	Urban wastewater
Value-added waste product	Reclaimed water for domestic and industrial use
Geography	Seasonally or continuously water short areas where urban and agricultural water demands could be better aligned
Scale of production	Medium- to large-scale (no defined range)
Supporting cases in the book	Mashhad, Iran; Llobregat delta, Spain
Objective of entity	Cost-recovery [ ]; For profit [ ]; Social enterprise [X]; Insurance [X]
Investment cost range	Can vary in large margins depending on (i) how far existing treatment infrastructure meets standards for irrigation, and (ii) distance for water transport
Organization type	Public, public-private, private
Socio-economic impact	Increased freshwater supply for urban households in periods of drought; guaranteed agricultural supply with reclaimed water in all seasons
Gender equity	Beneficial in particular to urban women and children due to time savings in water access; improvement in hygiene and living conditions 

Business value chain

To address increasing urban water demands in basins with limited water resources, or to cope with severe periods of drought, water reallocation within and across basins can be important adaptation strategies. Even without increasing the overall water volume, reallocating freshwater from agriculture to urban use in exchange for reclaimed water can help within the same basin urban needs, and help optimizing water allocations with sector specific water quality requirements. Such a water swap requires investments in appropriate treatment as well as incentive systems that farmers actually release their surface- or groundwater for urban use. This water can then be sold at a higher price to urban consumers than farmers would ever pay. The obtained revenues can support cost recovery of water transport and treatment, with an increasing probability of a positive benefit-cost ratio the larger the water volumes exchanged (Figure 248). The situation looks even better from an economic perspective: In the case of Spain, the direct and indirect costs of the affected regional economy due to multiple months of water scarcity in 2007–2008 were estimated at EUR1605 million or 0.48% of the regional GDP. The order of magnitude of these estimates is similar to others reported in the USA and Australia in recent years and easily outweighs the total investment costs in climate change adaptation measures in the region, including wastewater conveyance and treatment for reuse (Martin-Ortega et al., 2012).

FIGURE 248. VALUE CHAIN SCHEMATIC – INTER-SECTORAL WATER EXCHANGE



The business concept depends strongly on the incentives offered to (and accepted by) farmers, i.e. the contractual agreement (such as transfer of water rights) as otherwise farmers might absorb the wastewater to expand their operations without releasing freshwater. The exchange might only work where defined water rights exist, freshwater can be transferred to urban consumers without allowing access by third parties, and wastewater has to be redirected to farmers, e.g. pumped upstream (from city to farmers) as otherwise at least some downstream farmers will be able to access the urban return flow without contract.

Business model

This business model transfers freshwater from agricultural use to urban areas for domestic use in exchange for treated wastewater. This model is complex as it can entail many partners across the agricultural – water supply – wastewater and health sectors, different time horizons and mechanisms to support farmers' buy-in.

The main contract is between the public or private water utility and the farmers or their water users associations. The urban partner has to invest in additional treatment capacity as conventional treatment might result in water with too high in contaminants or salinity for crop irrigation. In addition, investments in water conveyance are needed although in many situations one of the flows might follow gravity.

Contracts can span the whole year where urban areas face a permanent supply deficit or be seasonal. If seasonal, the water swap can be limited to certain months or only be activated in times of severe drought. Water volumes can be defined or remain flexible according to the supply gap. Obviously, the pay-back period for treatment infrastructure and water conveyance increases when actual water swaps remain seldom, and/or volumes are low, like in the case of the Llobregat delta. However, in this case, the investment is more like a water supply insurance for parts of the 1.6 million city of Barcelona, aside other, and often more expensive, risk reduction and mitigation measures (desalination, long-distance water transfer).

Farmers, who have to give up on parts or all of their freshwater rights, need to understand the reasons and incentives to accept what looks per se as a disadvantage. These investments in awareness creation and incentives, and the contract, which builds on them, are the heart of the business model. The incentives can have pull and push factors. Depending on the local context, the authorities might limit farmers' freshwater withdrawal through regulations for times of drought while offering reclaimed water as substitute. To support farmers acceptance, the volume of supplied wastewater, can, like in the case from Iran, be higher than the released freshwater. Obviously, options to charge farmers for the water could be counterproductive. In contrary, wastewater acceptance could be bundled with financial incentives, such as access to micro-credit. Accompanying training in its safe application, protective gear and awareness creation on reduced fertilizer needs should be part of the package. Most important, as the studied cases stress, is the reliability of the supply and an acceptable water quality for plant growth. Social and economic benefits of the water exchange will be very high as the case from Iran shows where households and the local (tourist) economy depend on the additional freshwater year-round (Figure 249). On the other hand, the economic damage can be very high if a city is not prepared to adapt to such climatic extremes as the case from Spain shows.

Potential risks and mitigation from the urban perspective

In designing any optimized business model based on case studies, it is assumed that generic business risks are known and will be taken care of. However, some risks might be more model specific and will be acknowledged in the following:

Market risks: The market could be characterized as fragile as business success depends on willingness and availability of enough farmer or farmer associations to exchange freshwater against reclaimed water, which appears on the first view as a 'bad deal'. The business thus requires awareness creation on the reasons for the exchange, education on the advantages of wastewater (nutrients, reliability) and in addition tangible incentives for the farmers to accept the swap; all under the assumption of a water supply gap, thus a market for the released freshwater. Where urban water is constantly in short supply, long-term contracts would have an advantage; where the exchange is more an instrument for time of water crisis, also flexible contracts are possible. Market risks might be lower in societies where farmers have limited political power to negotiate agreements in their interests.

Competition risks: Different perspectives of competition are possible in a water swap:

a) farmers continue using freshwater;
b) the city receives freshwater through desalination or long-distance transfer at lower costs or less (human) risks (as the water exchange requires negotiations with farmers, reliance on behaviour change, etc.); and

FIGURE 249. BUSINESS MODEL CANVAS – INTER-SECTORAL WATER EXCHANGE FROM THE PERSPECTIVE OF THE WATER UTILITY

KEY PARTNERS

- Farmers or their associations
- If available, private entity managing water supply and sewerage
- Authorities (e.g. health, agriculture)

KEY ACTIVITIES

- Awareness creation for water swap
- Negotiation of water swap
- Treat wastewater fit for irrigation
- Convey wastewater to farmers/ freshwater to city
- Monitoring of water exchange agreement
- Households water supply
- Selling fresh water

KEY RESOURCES

- Treatment technology
- Capital
- Legal entitlement to exchange water rights

VALUE PROPOSITIONS

- Mitigating conditions of drought or general freshwater shortage through inter-sectoral water reallocation

CUSTOMER RELATIONSHIPS

- Negotiations to agree on formal contracts
- Inter-institutional collaboration
- Automated billing services to urban households

CHANNELS

- Negotiation roundtables
- Piped supply, direct or bulk sales
- Automatic billing through internet or supermarkets

CUSTOMER SEGMENTS

- Irrigating farmers
- Water demanding industry
- Urban residents

COST STRUCTURE

- Capital investment in treatment and water conveyance
- O&M (in particular water pumping, quality monitoring)
- Cost of awareness campaign for exchange, and safe wastewater reuse training

REVENUE STREAMS

- Sales of wastewater (optional)
- Sales of gained fresh water
- Indirect revenues (saving on socio-economic costs and damage claims from inability to supply water in (prolonged) periods of drought)

SOCIAL & ENVIRONMENTAL COSTS

- Possible health risks for farmers and consumers if wastewater quality does not meet agreed standards, or gets mixed with untreated wastewater before use, and insufficient risk reduction options have been put in place

SOCIAL & ENVIRONMENTAL BENEFITS

- Climate change adaptation measure to reduce the impact of extended water scarcity on agriculture and society
- Contribution to food security and continuing social welfare

c) technical advances allow to treat wastewater to potable quality making the swap redundant (assuming the water consumer accepts the reclaimed water).

Technology performance risks: The technology needed to upgrade existing treatment plants to meet the WHO guidelines for wastewater reuse in agriculture are common and in general not at risk of failure. However, the technology depends on political will and investments to meet the contractual quality and quantity targets the farmers are expecting. A severe performance risk concerns the limitations of the swap. In times of prolonged drought, also farmers' freshwater supply might decrease, reaching a limit where there is no more water to swap.

Political and regulatory risks: The business requires that farmers have well defined water rights or entitlements, which can be transferred, and regulations that allow the use of (partially) treated wastewater on farms serving local markets. Particular challenges relate to the regulation of groundwater usage and rights, e.g. where urban and rural users share the same aquifer. This also applies to the need of defining the ownership of raw wastewater as well as reclaimed water.

Social equity related risks: The model links different interest groups in need of water: farmers and urban dwellers/industry. This requires an inclusive process of planning and implementation where all parties can express their interests during fair contract negotiations. The reality might look different depending on the political power farmers have compared with the significant power of urban centers.

Where women farmers had no water rights before the swap, the model will not improve their situation unless the contract with the local community earmarks additional entitlements to reclaimed water for women. The swap is considered to have more advantages of social nature for women in the urban sector which vary with the scale of the prevented water shortage in terms of time and cost savings in water access, maintaining standards of hygiene and general living conditions.

Safety, environmental and health risks: Foreseeable health risks arise from the use of partially treated wastewater on farms, to farmers themselves, or, depending on the produce and the way it is consumed (e.g. cooked or uncooked) also other stakeholders along the value chain (Table 59). Perfectly treated wastewater which takes care of all pathogens, as well as inorganic and organic contaminants is still seldom, especially in low-income countries. Risks may be mitigated by following the WHO Sanitation Safety Planning process, including quality control measures or by regulation on the type of crops allowed to receive wastewater. As the Iran case showed, not only the quality of the replacement water matters, but also if the treated effluent is mixed with untreated wastewater before farmers access it. Therefore, this model should include the adoption of the multi-barrier approach for health risk reduction along the farm-to-fork value chain (WHO, 2006, 2015; see the introduction to Chapter 18).

Business performance

The model ranks high on the innovation criteria as it involves diverse actors across sectors and extends the value chain beyond cost recovery to social gains. The **scalability** of the model is contractually defined by the water volumes which have been negotiated between the parties, but ultimately by the physically available wastewater volume (and quality) which the city can offer to farmers as freshwater replacement. The essential building blocks for scaling are the existence of additional capacity to treat wastewater, latent irrigation demand in the area, and cooperation among farmers, industry partner, and municipality.

Where alternative adaptation measures to drought are not feasible, like seawater desalination, water swaps with farmers are possible if farmers can be convinced and incentivized to release their freshwater

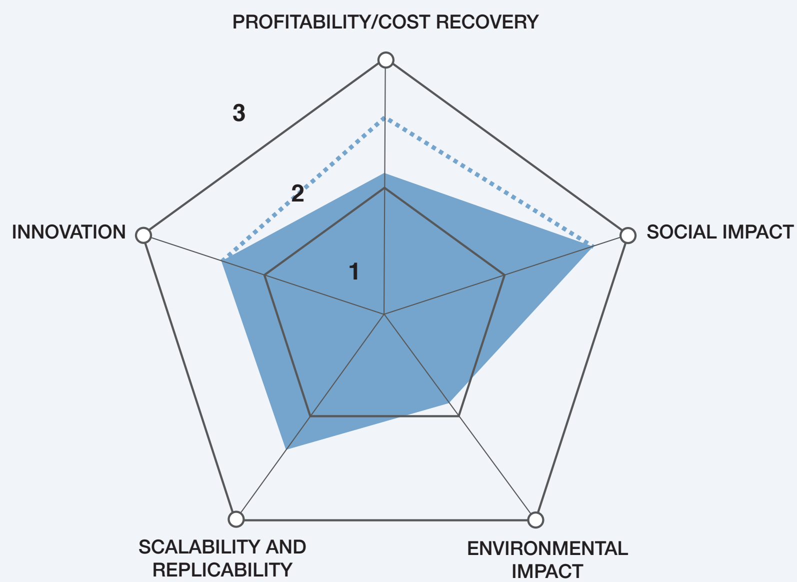
TABLE 59. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 20

RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR/ ODOR	INSECTS	WATER/ SOIL	FOOD	
Farmer						Higher risk possible where reclaimed water offered to farmers is poorly treated WHO's multi-barrier approach highly recommended along food chain
Community						
Food consumer						
Mitigation measures				Pb Hg Cd	Pb Hg Cd	

Key: NOT APPLICABLE; LOW RISK; MEDIUM RISK; HIGH RISK

rights, or do not have sufficient political power to resist. There are different options to facilitate farmers' buy-in, of which the receiving water quality ranks highest. Surplus water allocations appear as another strong factor for decision support. The actual amounts to be exchanged, and the timing, depend on the local freshwater deficit and regularity of supply.

FIGURE 250. RANKING RESULTS FOR THE INTER-SECTORAL WATER EXCHANGE BUSINESS MODEL



Note: The dotted line represents the anticipated change in returns under increasing periods of drought until the available water limit has been reached.

The water swap has a high potential for **replication** wherever cities outgrow local water supply. Cost recovery (from the urban sector) depends on the frequency and volume of the exchange. However, like with any insurance scheme, this is foremost a social responsibility model where the investment will pay off with the occurrence of any prolonged drought given the associated financial and economic losses, which will accompany any water supply scheduling or interrupting, aside the social and health related challenges. Depending on the available wastewater volume also ecosystem services can be supported with reclaimed water, beyond what Figure 250 indicates, although under severe drought highest priority is usually given to immediate socio-economic needs and benefits.

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CASE

Growing opportunities for Mexico City to tap into the Tula aquifer (Mexico)

Pay Drechsel, George K. Danso and Manzoor Qadir

Supporting case for Business Model 21	
Location:	Mezquital Valley, Mexico; Mexico City
Waste input type:	Urban wastewater
Value offer:	Agricultural and potable wastewater use
Organization type:	Public and private partners
Status of organization:	Irrigation since 1912; new treatment plant since 2016; potable reuse expansion to Mexico City under review
Scale of businesses:	Large
Major partners:	National Water Commission (CONAGUA), local, state and federal Government; Mezquital Valley Farmers and Water User Associations

Executive summary

This business case describes the double value proposition of (i) producing annually crops worth USD 400m through wastewater irrigation; and (ii) generating nearly potable water through the combination of conventional and natural wastewater treatment (aquifer recharge).

The Mezquital (or Tula[1]) Valley of Mexico is well-known for its large-scale wastewater irrigation on about 90,000 ha and its time (over 100 years) of operation which make the case in many textbooks a unique example of wastewater use in the global context. Until recently, the water was to 90% untreated depending on natural treatment processes which could not eliminate risks for the environment and human health. This situation has now been improved through the construction of new wastewater treatment plants, including the 800 million gallon-per-day (35m^3/s) Atotonilco mega plant which is one of the largest in the world, cleaning about 60% of the urban wastewater released from a population equivalent of 10.5 million people of the Greater Mexico City.

Although the value of irrigated food production received so far most attention, the significant rise of the groundwater level in the valley is shifting the attention to the use of its aquifer for supplying aside local communities in the valley also Mexico City with water. The city faces a long severe water crisis, and is running out of cost-effective options for its freshwater supply. The government's allocation of USD 255 million for tapping into the Tula aquifer to reduce the water deficit of Mexico City will make the city its own downstream water user to the direct and indirect benefit of several million urban dwellers.

KEY PERFORMANCE INDICATORS (ONLY ATOTONILCO WWTP, STATUS 2016)						
Land use:	159 ha (plant area)					
Water use:	$35m^3/s$ wastewater treated					
Capital investment:	USD 786 million (numbers vary with source and reference year)					
O&M:	USD 81m per year					
Output:	Up to 90,000 ha of irrigated fodder and food crops, aside large-scale wastewater driven aquifer recharge of about $25–39m^3/s$, which is retrieved in the valley for different purposes including domestic water supply ($6.2m^3/s$ envisioned for Mexico City)					
Potential social and/or environmental impact:	Job creation along the value chain, savings for advanced treatment, increased soil fertility and water supply for addressing urban food needs; nutrient recycling (reducing additional N and P fertilizer needs), aquifer recharge and the provision of drinking water within the valley and for Mexico City					
Financial viability indicators:	Payback period:	N.A.	Post-tax IRR (Atotonilco):	14.2	Gross margin:	N.A.

Context and background

About 70% of the 21 million urban dwellers of Mexico City depend on groundwater as a source of drinking water. Overexploitation of groundwater by at least 117% resulted within the city in soil subsidence at the rate of 5–40cm annually, increasing the cost of water supply and urban drainage, affecting transport (metro) and built infrastructure. Alternative options to improve urban water supply are long-distance water import and a large-scale leakage control program. Both options face their own challenges, making wastewater reuse, either directly after treatment, or after use in irrigation from the recharged aquifer, cost-effective complementary measures (Jimenez, 2014). Already today, the Tula aquifer, which derived to 90–100% from former wastewater, supplies the local population with drinking water (17%), while supporting agriculture (38%), industry (33%) and other uses (12%).

Irrigation, especially with water rich in nutrients and organic matter, is in high demand as the climate is semi-arid and soils are poor. On the request of local farmers around 1920, the government supported a complex irrigation system in the valley, which constituted recognition, although informal, of the use of non-treated wastewater to irrigate crops. Later, the farmers requested the concession of $26m^3/s$ of Mexico City's wastewater – the entire quantity available at that time. Consent was granted by the President in 1955 (Jiménez, 2009). The use of wastewater quickly became a source of livelihoods as it enabled crops to be grown all year round. Land with access to wastewater costs more than twice the rent (USD 1,000/ha) than land with access to rain water (USD 400/ha) only.

Irrigation water quality in the valley varies regionally, with about 10,000 ha using raw wastewater, 35,000 ha diluted wastewater, 25,000 ha partially treated wastewater, and other areas benefitting from aquifer recharge (Navarro et al., 2015). These shares will change towards increased safety with the newly installed treatment capacity which can absorb 60% of Mexico City's wastewater and will release $23m^3/s$ directly for irrigation, while $12m^3/s$ will support indirect reuse, local reservoirs and the environmental flow of the Tula river.

Due to the high irrigation rate as well as storage and transport of wastewater in unlined dams and channels, the aquifer is unintentionally being recharged on a vast area at a rate between 25 and $39m^3/s$ which is exceeding natural recharge 13 times, and led to an increase of the groundwater level between 1938 and 1990 by 15–30m with new springs appearing and a higher water volume in the Tula river through groundwater inflow (Jimenez, 2014).

Market environment

There are two complementary water markets, Mexico City and the Tula Valley. While the valley needs the urban wastewater for its economy, the city needs the valley to absorb with limited costs its effluent.

a) According to Jiménez (2014), Mexico City uses about 86m^3/s of water derived from local wells (57m^3/s), long distance transfer (20m^3/s), surface water (1m^3/s) and is using all its reclaimed water (7.7m^3/s). Water consumption is mostly for domestic use (74%), local irrigation (Mexico Valley, 16%) and industrial and other uses (3%). For 2010, a water deficit of 15–38m^3/s was estimated to supply the increasing population and control soil subsidence within the city. Among the measures to close the gap are a long-term leakage control program and the careful protection of the inner-urban aquifer. Additional long distance supply will remain a critical component but is increasingly opposed by local population at the source, or faces very high pumping costs, not because of the distance, but 1,000–1,500m differences in altitude to reach Mexico City. Extending wastewater reuse from the Tula aquifer would offer at much lower vertical difference, and is increasingly considered a feasible and cost competitive option, although post-treatment is required to eliminate remaining water quality concerns (Jiménez, 2014; Navarro et al., 2015).
b) The Tula Valley receives on average about 60m^3/s of Mexico City's wastewater. Irrigation to supply Mexico City with food is the economic backbone of the area, as the additional water allows to grow two to three crops instead of one, and achieves 67–150% higher yields compared to freshwater irrigation. Direct and (via aquifer recharge) indirect wastewater use in the valley supports also other economic activities. Although water quality from the Tula aquifer appears in large better than of conventional wastewater treatment, the newly commissioned WWTPs are expected to further reduce gastrointestinal diseases (Contreras et al., 2017), and support market demand.

Both (rural and urban) markets are not mutually exclusive if the extraction points are well distributed, given that groundwater recharge is exceeding local water needs. The transfer of about 5m^3/s consisting of groundwater from the Mezquital (Tula) Valley to Mexico City has been initiated under Mexico's National Infrastructure Program and was in February 2017 under review (CONAGUA, 2017). If successful, higher water volumes are available.

Macro-economic environment

One of the main aims of Mexico's current National Water Program is to treat and reuse wastewater. In recent years, the percentage of collected wastewater that is treated has risen from 23% to 36%, and the goal is to reach 100% of municipal wastewater by 2020 and industrial wastewater by 2025. The gap is not caused by missing water demand, but treatment capacity. The use of **un**treated wastewater for irrigation is already supporting the livelihoods of several hundred thousand people. Agricultural production for 2011–2012 in the two main irrigation districts of the Tula Valley generated about USD 400 million in crop outputs (CONAGUA, 2013). To replace untreated with treated wastewater, the government catalyzed a multi-billion US Dollar investment program to improve urban water supply, drainage and wastewater treatment. Currently, Mexico City is using 100% of its reclaimed wastewater, making the city in relative terms one of the global reuse leaders. The new investments are paving the way to become also in absolute numbers a global leader given that the new treatment plants will multiply the amount of reclaimed water of immediate use in the Tula Valley. The additional allocation of USD 255 million for tapping into the Tula aquifer to reduce the urban water deficit makes Mexico City its own downstream water user. Aside water imports from Mezquital, also transfer from other basin remains important, but is increasingly objected due to negative local impacts like reduced irrigation areas.

Business model

The main 'value proposition' was and is the use of wastewater for crop production, turning an unwanted discharge into a resource which is mobilizing annually a value of several hundred million US Dollar (see above). A small part of these revenues is spent on O&M of the irrigation infrastructure, complemented by CONAGUA subsidies.

With 90–100% of the valley's aquifer being formed by Mexico City's wastewater, groundwater use for various economic activities offers a second waste-based value proposition. The treatment provided by the Atotonilco plant will support surface and groundwater quality, although for potable reuse further membrane filtration before reuse has been suggested.

Supplying Mexico City with groundwater from Tula could generate about USD 150m/year based on the upper water tariff, which is however unlikely to cover the operational costs, while the expected economic benefits will be far beyond this value. Taking as example the Gutzamala long-distance water transfer, which however requires more energy for a much higher difference in elevation, its annual operational cost is covered to 48% through user fees and 52% by federal funds. Without changes in water tariffs, the business model (Figure 251) will remain foremost a social one, subsidized by the municipal and federal governments, which is however well justified by the magnitude of reduced externalities, like damages to buildings, streets, sidewalks, sewers, storm water drains and other infrastructure due to land subsidence, as well as the magnitude of community benefits due to appropriate water supply.

Value chain and position

The traditional value chain of transforming urban wastewater into an agricultural asset, involving local farmers, water user associations and traders, is since decades common reality in the Tula Valley (Figure 252). To transport water from the replenished aquifer back to Mexico City appears cost effective and is under review (CONAGUA, 2017). It could potentially face institutional obstacles in view of water entitlements (FAO, 2010) although in general all goods found beneath the surface in Mexico belong to the country according to the Mexican Constitution, with CONAGUA in charge of groundwater management. While in other remote areas where CONAGUA is sourcing water for Mexico City, water competition is increasing and so local resistance, there should be less reason for competition in view of the boosted Tula aquifer.

Institutional environment

Mexico's National Water Law, passed in 1992, provides the legal framework for water management in Mexico. It states that the use of the nation's water or the right to discharge wastewater will be carried out by concessions from the Federal Executive Branch, through the National Water Commission (CONAGUA). CONAGUA also allocates the water-related budget for the 32 states in Mexico. The budget for water is approximately 60% of the total environmental budget in Mexico. One of the states is the State of Mexico, which includes the large majority of Greater Mexico City (Mexico City Metropolitan Area) with its 21 million people that is composed of 16 Municipalities, as well as a larger number of adjacent municipalities. Governmental responsibilities are complex given the stakes of the Federal Government, the government of Mexico City, and the government of the State of Mexico, resulting in fragmented responsibilities[2]:

- The Federal government is in charge of regulating the use of water resources, contributing to the financing of investments and supplying bulk water from other basins through CONAGUA.
- CONAGUA which is operating under the Ministry of the Environment and Natural Resources is also responsible for upstream parts of the wastewater irrigation infrastructure in the Tula Valley and its operation, while local water user associations (WUA) are in charge of downstream irrigation management and user tariffs.

FIGURE 251. BUSINESS MODEL CANVAS – WASTEWATER FOR IRRIGATION AND GROUNDWATER RECHARGE

KEY PARTNERS
- National and State Water Commissions
- Municipalities
- Farmers and their WUAs
- SACMEX
- ATVM
- Banks

KEY ACTIVITIES
- Wastewater transport and treatment
- Reclaimed water distribution, post-treatment and sale

KEY RESOURCES
- Urban wastewater
- Finance
- High level engineering skills
- Positive public perception

VALUE PROPOSITIONS
- Turning wastewater into water for irrigation and potable reuse at scale

CUSTOMER RELATIONSHIPS
- Formal agreements between all partners
- Automatic billing of domestic water users

CHANNELS
- Water delivery through pipes and irrigation canals
- Water bills can be paid at most banks, major grocery stores, some convenience stores, or the water company

CUSTOMER SEGMENTS
- Farmers located in the Mezquital Valley
- Urban dwellers in the Valley and of Mexico City

COST STRUCTURE
- Capital investment and O&M of water treatment, long distance transport and irrigation schemes
- Health risk monitoring and reduction costs

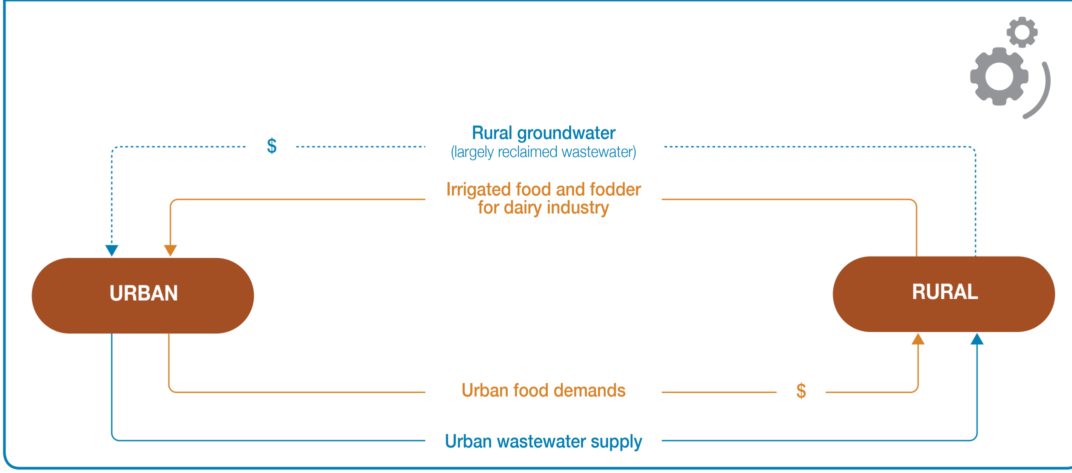
REVENUE STREAMS
- Bulk water sales to WUAs, and fees charged to individual farmers
- Bulk water sales to municipal water suppliers, and household charges via water bill

SOCIAL & ENVIRONMENTAL COSTS
- Likely health cost for farmers and potentially also for consumers through diseases derived from unremoved contaminants transferred via the food chain or reclaimed water
- Risk of long term soil contamination (e.g. by heavy metals)

SOCIAL & ENVIRONMENTAL BENEFITS
- Benefits for rural and urban food and water security with value generation across sectors and value chains
- Reduction in public health expenditure through increased conventional and natural wastewater treatment and water availability
- Improvement in livelihoods and ecosystem services

- In Mexico State, the State Water Commission (CAEM) buys bulk water from CONAGUA, transmits it through its own bulk water infrastructure and sells it on to its municipalities. CAEM also monitors water quality, operates wastewater pumping stations and several wastewater treatment plants.
- The municipal governments in the State of Mexico and Hidalgo are in charge of water distribution and sanitation for their constituents. In Mexico City, for example, the water operator (Sistema de Aguas de la Ciudad de México or SACMEX) provides potable water, drainage, sewerage, wastewater treatment and water reuse services.

FIGURE 252. RURAL-URBAN LINKAGES BETWEEN THE MEZQUITAL VALLEY AND MEXICO CITY



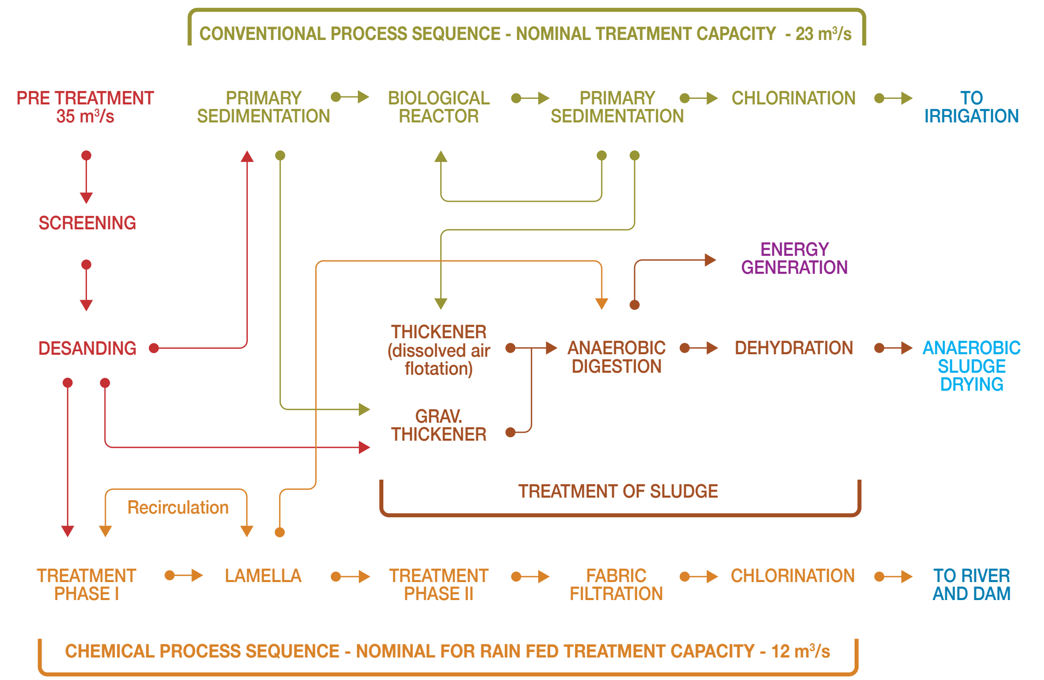
The major program governing recent water developments is the Water Sustainability Program of the Valley of Mexico, which envisages a series of infrastructure investments supported by the drainage, water supply and wastewater treatment to serve the Mexican capital. The program is supported the National Infrastructure Program but relies heavily on private sector funding. One target is to increase the city's water supply by 14m^3/s with about 5m^3/s consisting of groundwater from the Tula Valley, at an estimated cost of USD 255 million[3]. The second-largest source of additional water will be mobilized through an exchange of treated wastewater for clean water at present used for green area irrigation (4m^3/s), at a cost of 140 million. Another 3m^3/s is envisioned to be gained through rehabilitation measures (Cutzamala system) and 2m^3/s would be made available from the Guadelupe dam in Mexico state[4]. The Sustainability Program governs also the construction of the Emisor Oriental (Western Sewer) and the Atotonilco wastewater treatment plant. The plant has been constructed and will now be operated by the Aguas Tratadas del Valle de Mexico (ATVM) private sector consortium.

Technology and processes

Discharge of wastewater from the Greater Mexico City into its sewer network is estimated around 41 to 44 m^3/s. Considering rainfall, the total average flow managed by the sewer system in the Metropolitan Area is around 60 +/– 15m^3/s. This wastewater is sent by gravity and pumping via five artificial exits to the Tula Valley. The latest tunnel, the East Emitter (Emisor Oriente) which was end of 2016 still in construction has a capacity of 150m^3/s and is 62 km long. Discharge from the tunnels will be primarily treated at the Atotonilco wastewater treatment plant which has a total treatment capacity of 35 m^3/s (Figure 253), with an additional hydraulic capacity of 20% to manage storm water that mixes with the wastewater, giving a maximum capacity of 42 m^3/s in rainy periods. Till the East Emitter is operational, the plant receives the flows from the older Central Emitter.

The treated water will support direct and indirect wastewater irrigation, and based on farmers' request try to limit the removal of crop nutrients during wastewater treatment. The sludge produced by the Atotonilco plant will be stabilized by anaerobic digestion and the gas produced will be used for power cogeneration, providing according to different sources 60–80% of the plant's own electricity requirements. The plant has an estimated lifespan of 50 years. There are also several smaller wastewater treatment plants in construction which together will add another 10m^3/s treatment capacity.

FIGURE 253. DIAGRAM OF THE ATONONILCO TREATMENT PROCESS.



Source: CONAGUA, 2017.

Due to unlined water reservoirs and irrigation channels, the Tula aquifer is unintentionally being recharged at a rate of (more than) 25m³/s, exceeding natural aquifer recharge multiple times. Aside local groundwater use, a part of the excess groundwater has been proposed to be pumped from twelve batteries of extraction wells in the Mezquital Valley over 80 km and an altitude difference of about 500 m back to Mexico City. Flow rate of extraction will be about 6.4m³/s, and at the destination at least 4.2m³/s (CONAGUA, 2017). Treatment before reuse to address potential health risks is highly recommended, especially if the water is used like in this case for potable purposes.

Funding and financial outlook

Local financing for water infrastructure comes from federal, state and municipal resources. CONAGUA which channels federal (governmental) funding to municipal and rural projects, and the National Bank of Public Works (BANOBRAS) which provides financing, subordinated debt and capital. States, municipalities and local authorities have very limited financing capacity for new infrastructure. CONAGUA is also a fiscal authority, charging duties for the use of Mexico's water resources which includes water supply as well as (the use of water receiving) wastewater discharges.

Irrigation: CONAGUA manages irrigation water supply across Mexico through local WUAs or smaller operators which are charging their farmers for O&M of the irrigation infrastructure. The tariff is to be calculated every year to cover O&M costs of the irrigation system. Fees are assessed by total area, by irrigated area, by type of crop, and by cultivated area, and only in a few cases by water volume. A part of the fee supports CONAGUA's maintenance of upstream infrastructure, which remains otherwise subsidized.

Rural-urban water supply: After construction of the planned pipeline, its operation might be – like in similar cases – with the Mexico Valley basin agency (OCAVM) for CONAGUA, supplying CAEM and SACMEX with water for the supply of communities and households. Water tariffs are set locally by the authorities of each municipality depending on the provisions of each state's legislation, and include fixed costs, proportional costs according to the water used, with or without costs for sewerage and wastewater treatment and taxes.

Wastewater treatment: The Atotonilco project was assigned by CONAGUA to a private sector consortium for a design-build-operate-transfer (DBOT) contract, with a 25-year construction and operating period. The ATVM consortium partners financed 20% with equity, and 31% with credit from BANOBRAS, while the National Development Fund of Mexico (FONADIN) contributed a subsidy of 49%. The winning bid was chosen on the basis of the lowest consumer tariff requested. The concessionaire is repaid, however, from CONAGUA's budget. CONAGUA is charging water use and discharge duties and is paid for the provision of bulk water, which the municipalities supply to households. The household water bill usually includes a share for sanitation/wastewater management (Figure 254). These tariffs are generally not sufficient to cover the costs of providing the services.

More information on financing water services (capital and operational costs) can be found in CONAGUA (2010).

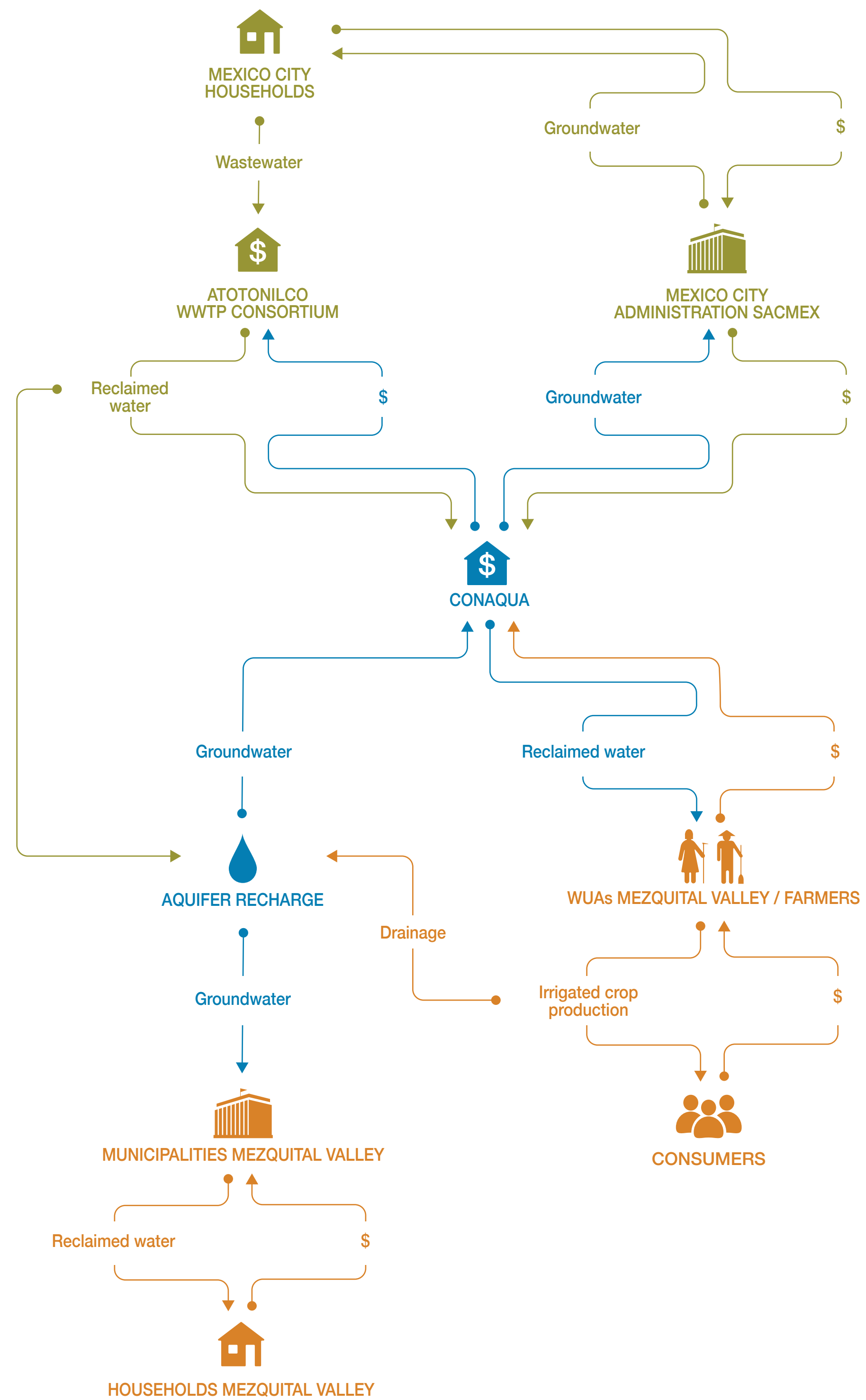
Socio-economic, health and environmental impact

Mexico City was for over a century taking advantage of natural wastewater treatment in the Tula Valley, saving costs otherwise required for treatment infrastructure. This system appeared in large as a win-win situation as the city got rid of the water while the local economy in the Tula valley transformed the wastewater in an economic asset via additional crop harvests, higher yields per hectare, etc. To control possible health risks, legislations requesting crop restrictions are in place, though with limited enforcement, resulting in a long history of increased diarrheal diseases linked to water exposure (Contreras et al., 2017). Risks will also remain after the Atotonilco wastewater treatment plant is fully operating as it will only treat 60% of the wastewater released in the valley. However, it is a giant step forward given that before only 6–11% were treated. The treatment plant is supposed to benefit 700,000 people in the Mezquital valley, of which 300,000 live in irrigation.

Especially for aquifer recharge, natural land treatment will remain important. So far, the water passing the soil and unsaturated zone above the Tula aquifer is resulting in groundwater of a quality exceeding the one of conventionally treated wastewater. The higher groundwater table and the appearance of new springs are supporting different economic sectors including potentially several million households back in Mexico City once the long-distance transfer is in place. Water extraction from the Tula aquifer can also positively influence groundwater induced soil salinity in the valley. However, soil characteristics and hydro-geology vary regionally and so their filter characteristics. In fact, it is not known when the natural filter system might reach saturation. There is also the risk that the new treatment plants will remove organic matter from the wastewater which is needed to absorb contaminants when passing the soil. There could also be safety concerns due to the use of agro-chemicals by farmers. Thus, for potable use, additional membrane filtration has been recommended, especially in view of 'emerging contaminants', such as pharmaceutical or pesticide residues with so far unknown threshold values (Navarro et al., 2015).

Finally, in line with the recommendations of the National Water Plan (2012–2018), the Atotonilco wastewater treatment plant is covering to a large percentage its own water (92%) and energy (60–80%) needs and reducing greenhouse gas (GHG) emissions by an average of 400,000 tons of CO_2e per year.

FIGURE 254. RURAL–URBAN WATER AND WASTEWATER TRANSACTIONS BETWEEN MEXICO CITY AND THE MEZQUITAL VALLEY (SIMPLIFIED)



The project is investing in reforestation using native plant species, with the aim of recovering and improving the quality of environmental services on the site.

Scalability and replicability considerations

This business case describes a rural-urban win-win situation with a double value proposition of (i) producing annually crops worth USD 400 million through the use of unwanted wastewater; and (ii) generating nearly potable water through the combination of conventional and natural wastewater treatment (aquifer recharge), resulting potentially in USD 150 million revenues through the water tariff.

The key drivers for the business which are also common in other regions are:

- Rapid urbanization resulting in large volumes of unwanted wastewater discharge and groundwater recharge.
- Water scarcity resulting in high demand for surface and groundwater for multiple financial and economic benefits.

Other drivers which are not always common:

- Governmental capital investments and subsidies based on expected large economic benefits.
- Government consent in providing farmers with (untreated or partially treated) wastewater and irrigation infrastructure.
- Vast aquifer with very high natural recharge rate.
- Scale of reuse making it a powerful economy.
- Alternative options for upgrading urban water supply face increasingly challenges.
- Significant research on health risks and options for risk reduction.
- World class engineering (wastewater treatment and long-distance/high elevation water transfer).

A major issue associated with this model is the continuous use of in part untreated wastewater for irrigation and groundwater recharge. However, there are various options to limit related risks for human health, which can be tailored to the actual water use and its quality requirements.

Summary assessment – SWOT analysis

The described model is very promising because water is in high demand in both the Mezquital Valley and Mexico City and both locations are short in alternative options to direct or indirect wastewater use. Minimizing possible health risks will be the key to a sustainable rural–urban partnership where the economic benefits of water for domestic use, agriculture, industry and the environment will easily justify the capital investment as well as O&M costs. Figure 255 shows a condensed SWOT analysis for this business case in Mexico.

FIGURE 255. SWOT ANALYSIS FOR WASTEWATER REUSE INCLUDING RURAL–URBAN WATER TRANSFER FROM THE MEZQUITAL VALLEY, MEXICO

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Supply of large amounts of wastewater secured ▪ Farmers, authorities and legislations value wastewater ▪ Strong water demand from rural and urban users ▪ Financial support from the government available ▪ High engineering capacity	**WEAKNESSES** ▪ Wastewater treatment not covering all generated wastewater and types of contaminants ▪ Farmers' concerns that further treatment will remove crop nutrients ▪ High absolute cost of water transport and treatment
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Lower costs to supply Mexico City than via other long distance/high altitude transfers ▪ Strong and growing urban demand for expanding business ▪ Likely health risks for water consumers can be controlled ▪ Reduced soil salinization through groundwater use	**THREATS** ▪ Remaining health risks for farmers, consumers and potable water users have to be controlled to protect market demand ▪ Potential conflict due to unclear wastewater use rights ▪ Future competition for water reuse if acceptance grows

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Case descriptions are based on primary and secondary data provided by case operators, literature, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2016/17. As business operations are dynamic data can be subject to change.

Note

1 The Mezquital valley is located in the Tula Valley in the State of Hidalgo, 100 km north of Mexico City. In this case study the name Tula valley is mostly used except where a distinction is required.
2 https://en.wikipedia.org/wiki/Water_management_in_Greater_Mexico_City (accessed 12 Sept. 2016).
3 ibid.
4 ibid.

CASE

Revival of Amani Doddakere tank (Bangalore, India)

George K. Danso, Doraiswamy R. Naidu and Pay Drechsel

Supporting case for Business Model 21	
Location:	Hoskote[1], Bangalore, India
Waste input type:	Urban sewage (diluted with storm water)
Value offer:	Treated wastewater for irrigation, domestic use and restoration of ecosystem services
Organization type:	Public
Status of organization:	Fully operational: 2011
Scale of businesses:	Medium
Major partners:	Karnataka Department of Water Resources (Minor Irrigation); farmers at the Amani Doddakere tank. Indirectly: farmers along the lift irrigation transfer and the Hoskote Municipality

Executive summary

This business case describes the transformation of urban wastewater into an asset for peri-urban farmers and households through inter-sectorial water transfer for groundwater recharge. Excess water from Bangalore's highly polluted Yelemallappa Shetty tank[2] (YMST) is redirected over about 6.2 km to the Amani Doddakere tank (ADT) at Hoskote, reducing pressure on the sewage-fed YMST while partially restoring the ADT, a tank that was for over 18 years dried up.

The lift irrigation system was planned in the late nineties but only realized a decade later. The original idea was to directly feed the water in the irrigation channels at the ADT. Due to illegal tapping into the transfer canal and pipe, the water arriving at the ADT is however insufficient for this objective and most farmers benefitting from the transfer can be found between the YMST and ADT. However, through aquifer recharge, groundwater tables which had dropped below 1,000 feet (ca. 305m) in ADT vicinity, can now be accessed again, providing farmers and households quality water, either directly from wells or through water vendors with well access. The Hoskote Municipality started almost a 24/7 water supply after mandatory water treatment (chlorination). Before this, piped water was only available for short periods all few days. Capital and operational costs, the latter mostly for pumping (lifting) the water out of the YMST are moderate given the achieved benefits. Although the project might present primarily a social business model with still unvalued, social and environmental costs and benefits, operational cost recovery of up to 25% from farmers appears possible, while options on how to charge private water tankers remain to be explored. Although in this case, the recharged groundwater appeared to be of excellent quality and public perception very positive, for any replication of the model care has to be taken that the characteristics of the receiving

aquifer are known, and a well-defined institutional and legal framework provides capacity for dedicated environmental impact assessments (EIA) and water quality monitoring in view of long-term impacts.

KEY PERFORMANCE INDICATORS (2014/15)						
Land use:	20 km of wastewater pipeline / open canal					
Water requirements:	Lifting capacity of 0.26m^3 per second					
Capital investment:	USD 674,000					
Labor requirements:	Low in public sector, but high among benefiting farmers and private sector					
O&M:	USD 3000–3500 per month (mostly for pumping)					
Output:	5-6 MCM per year for up to 171 ha under irrigation					
Potential social and/or environmental impact:	200–500 farmers between the YMST and ADT. Direct and indirect supply also for several thousand households without well via piped and tanker water supply. Improved ecosystem services through biodiversity increase after lake restoration					
Financial viability indicators:	Payback period:	Not available (N.A.)	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Bangalore (Bengaluru), the capital city of India's Karnataka state, is with a total population of over 11.5 million people, the third most populous city of India. Bangalore's water demand-supply gap was estimated to be 750 million litres a day (MLD) in 2013, and is expected to increase to 1,300 million litres a day by 2026 (McKinsey and CII, 2014). The escalating water demands resulted in unsustainable groundwater extraction and correspondingly high wastewater generation. Although Bangalore is one of the most advanced cities in India with 3610 km of sewage lines and 14 sewage treatment plants, the sewer network is outdated, and less than half of the generated wastewater is captured and/or gets treated. The mix of untreated and treated wastewater pollutes local streams and [cascades of] freshwater reservoirs in and around the city. One of the largest tanks, the Yelemallappa Shetty tank (YMST) in north-eastern Bangalore, is such an example of an ecologically dying lake, increasingly filled up with city run-off, garbage and construction debris. Like 17 other (originally irrigation) tanks on the city outskirts, the YMST is under the management of the Minor Irrigation Department.

Further away from Bangalore, dried-up lakes are common. Despite an average of 800–900mm rain, many irrigation tanks have disappeared and their land was transformed for other use. In the case of Hoskote, a large county with 333 villages in Bangalore's vicinity, the local Amani Doddakere tank (ADT) dried up about 20 years ago, with groundwater levels dropping[3] over the same period by several hundred feet to a depth of more than 1,000 feet (Scharnowski, 2013). In the Hoskote municipality, the extracted 3.36 MLD of drinking water were by far not adequate to meet the 9.37 MLD water demand by Hoskote's ca. 60,000 inhabitants. To support all citizens, the government introduced a scheduled water supply, and made the process of getting permission to sink new borewells (bore holes) difficult.[4] However, under increasing water demand, owners of existing borewells started selling water to tanker companies.

With their livelihoods threatened, farmers from Hoskote requested in the late nineties from the Government of Karnataka to lift water from the YMST to the ADT in support of irrigation, a plan which was drafted in 1999, but only realized a decade later. By that time, the YMST had become a highly polluted water body. End of 2011, the scheme started transferring about 5–6 million cubic meter (MCM) of water from the YMST towards Hoskote. The original estimated cost was USD 579,000 which rose to USD 674,000 due to delays in completion. The ADT had an original capacity of 22.6MCM, with a command area of 940 ha and max. water surface area of 1,100–1,300 ha. The aim of the YMST lift irrigation scheme was to revive the ADT, support its irrigation channels and to recharge groundwater

and wells in the area. The wastewater which flows from the YMST to the ADT in part through a pipeline, in part through an open channel, attracted farmers to illegally tap at four to five locations into the resource to fill their tanks and enable ground water recharge for drinking and irrigation, fish rearing and cattle feeding. This resulted in significantly less water eventually arriving in the Doddakere tank, in particular not enough to supply the irrigation channels.[5] Still a part of the ADT got filled with about six feet of water, improving noticeably the groundwater table in lake vicinity from recently 1,000–1,200 feet to 800 feet or much higher. Based on the expected inflow of polluted water, authorities banned direct water use from the ADT, while indirect use via the aquifer provided water fit for irrigation.

Market environment

Under the common water scarcity and dependency on dwindling groundwater, demand for water, water transfers and groundwater replenishment are very high in Karnataka and beyond, and more lift irrigation projects of similar nature are under discussion (see below). Aside supporting agriculture, the 'new' water is also replenishing groundwater for domestic use, making the local water supplying agency as well as private water vendors key customers of any water transfer. All actual as well as potential beneficiaries expressed a high willingness to pay for water (Scharnowski, 2013) as all alternatives are more expensive, from buying water or motor pumps to borewell construction. Well construction is in fact farmers' main cost item as farmers enjoy a broad spectrum of subsidies such as free electricity (pumping), subsidized fertilizer and seeds (The World Bank, 2012). Farmers who lost access to water either had to buy it from other farmers, change their cropping to only rainfed systems or abandon agriculture.

Macro-economic environment

Although some governmental statistics might indicate a large number of households connected to piped water supply, water pressure, for example in Bangalore, is usually very low and access sporadic. A similar mismatch of statistics and reality is found in the sanitation sector where installed treatment capacities are not supported by the sewer network which is outdated and large amounts of wastewater end in streams and lakes. Thus, water supply remains a key challenge, and water transfer and reuse remain high on the policy agenda, also as lake restoration is strongly promoted in Karnataka.

However, implementation of water transfers is not straight forward. Although governmental programs and policies call for wastewater reuse, treatment at the right (reuse) location is seldom, and (untreated) informal wastewater irrigation remains most common (Amerasinghe et al., 2013; Gupta et al., 2016). Also aquifer recharge with wastewater falls in a grey area. Karnataka's first groundwater law, which came into effect in 2011, introduced regulations to monitor the number of bore wells and groundwater use, and that commercial bore wells could be subject to tariffs and caps on water withdrawal. However, law implementation and registrations remained limited (Borthakur, 2015), partly due to missing incentives to register as well as lack of clarity over the exact mandates of different authorities (Bangalore Water Supply and Sewerage Board, Department of Mines and Geology, Department of Water Resources), not to mention water quality issues where freshwater lakes turned into sewage ponds, or options for charging for water abstraction. Moreover, recent suggestions for lift irrigation schemes in Karnataka (e.g. the replenishment of 29 minor tanks around Hoskote and Chikkaballapur) got stalled due to objections raised by the neighboring state of Tamil Nadu fearing that these projects will affect Tamil Nadu's access to water in the shared Dakshina Pinakini River basin. Competition for water, independently of its quality, is high in the region.[6]

Business model

This is primarily a social business model with a potentially high pay off. The city is trying to reduce pressure on lakes with high sewage and storm water inflows in support of groundwater recharge in the water-scarce hinterland, allowing indirect (waste)water reuse for irrigation, household and environmental needs with ecological, economic and social benefits.

Revenues are theoretically collected by the Department of Irrigation, charging farmers per hectare, while households connected to meters pay for drinking water supply. Field surveys showed that farmers between the YMST and ADT would be willing to pay significantly above the current water rates if they could rely on the wastewater flow. The amounts would allow to cover about 25% of the operational and maintenance cost of the lift scheme (Scharnowski, 2013).[7]

The originally unintended primary beneficiaries of the water transfer are those institutions whose obligatory functions as per the Constitution of India is to provide drinking water to the people. However, there are no systems (yet) in place to fund the lift irrigation from revenues accruing in other sectors, like charging water vendors (or farmers) for abstracting replenished groundwater for sale.[8] Changes in tariffs for water use or electricity (pumping) are being discussed, also in light of regulating water abstraction than only revenue generation. Given the low water tariffs, the project is unlikely to financially break even, while the expected economic returns in terms of environmental and livelihood benefits are probably surpassing both, the investment and running costs of the lift irrigation scheme which easily justifies the social character of the business model (Qadir et al., 2014).

Due to immense water demand around cities, and the success of the Hoskote case, the social business concept has a strong replication potential, especially if water access between source and target can be considered in the project design. For the business model to be sustainable, it has to be based on principles of integrated water resources management (IWRM) with full stakeholder participation beyond the irrigation sector, and geo-hydrological assessments including continuous groundwater quality monitoring. Figure 256 shows the business model canvas.

Value chain and position

The value chain (Figure 257) shows current services as well as actually possible and potential (dotted line) revenue streams.

Institutional environment

What was originally planned as a simple transfer of normal irrigation water (and correspondingly did not involve other stakeholders) became much more complex when the system eventually started, and the lift irrigation scheme evolved into a complex system of wastewater use, lake rehabilitation, groundwater recharge and drinking water extraction, elements which concerns a range of departments, authorities, and initiatives in the state of Karnataka. Overlap in responsibilities as well as reassignment of responsibilities are common features. The construction, maintenance and monitoring of minor irrigation projects, i.e. those with a ‘culturable command area’ of 2,000 ha or less are under the purview of the Minor Irrigation Department. Most of the Department’s projects focus on surface water schemes while ground water schemes are dealt with in collaboration with the Department Mines & Geology (Groundwater Wing). The Minister for Minor Irrigation is also the chairperson of the governing council of the new (2015) Lake Conservation and Development Authority, which has members from several departments.

The Bangalore Water Supply and Sewerage Board (BWSSB) is responsible for providing drinking water supply to Bangalore City. The Karnataka Urban Water Supply and Sewerage Board is responsible for providing drinking water supply to urban areas throughout the state of Karnataka.

The legal framework influencing the extraction of groundwater are the Karnataka Groundwater (Regulation and Control of Development and Management) Bill (2009) and Act (2011) which basically lay down the application procedure for new borewells, process of registering and costs involved. Groundwater is considered the property of the government, and the drilling of borewells requires in the Hoskote area, like in several others harshly affected by groundwater depletion, official approval from the district committee. This resulted in a ban on new drilling of deep borewells in the area.[9]

FIGURE 256. BUSINESS MODEL CANVAS FROM THE PERSPECTIVE OF THE WATER PROVIDING DEPARTMENT OF WATER RESOURCES

KEY PARTNERS

- Hoskote town municipal council
- Urban Water Supply and Sewerage Board
- National Bank for Agriculture and Rural Development (NABARD)
- BMS College of Engineering, Bangalore

KEY ACTIVITIES

- To transfer water from YMST to Doddakere tank
- Operation and maintenance

KEY RESOURCES

- YMST surplus water
- Lift irrigation pump, pipeline and canal
- Financing
- Receiving tank

VALUE PROPOSITIONS

- Providing reliable access to water for irrigation and other needs through tank revival and groundwater recharge with significant livelihood benefits

CUSTOMER RELATIONSHIPS

- Formal relationship between the farmers and the Department of Water Resources (Minor Irrigation)

CHANNELS

- Direct contact with the farmers

CUSTOMER SEGMENTS

Directly

- Farmers

Indirectly

- Municipal water supply
- Water traders
- Households
- Fishermen

COST STRUCTURE

- Capital investment by Government
- Operation and maintenance by Government

REVENUE STREAMS

- Limited or no revenue from farmers but willingness to pay by farmers and other beneficiaries is high
- Revenue systems for other water users under discussion

SOCIAL & ENVIRONMENTAL COSTS

- Health risks likely for farmers accessing (illegally) untreated wastewater on the way to Hoskote or from the tank
- Groundwater quality development over time unclear, including possible increase in health related costs
- More mosquito related diseases in Hoskote

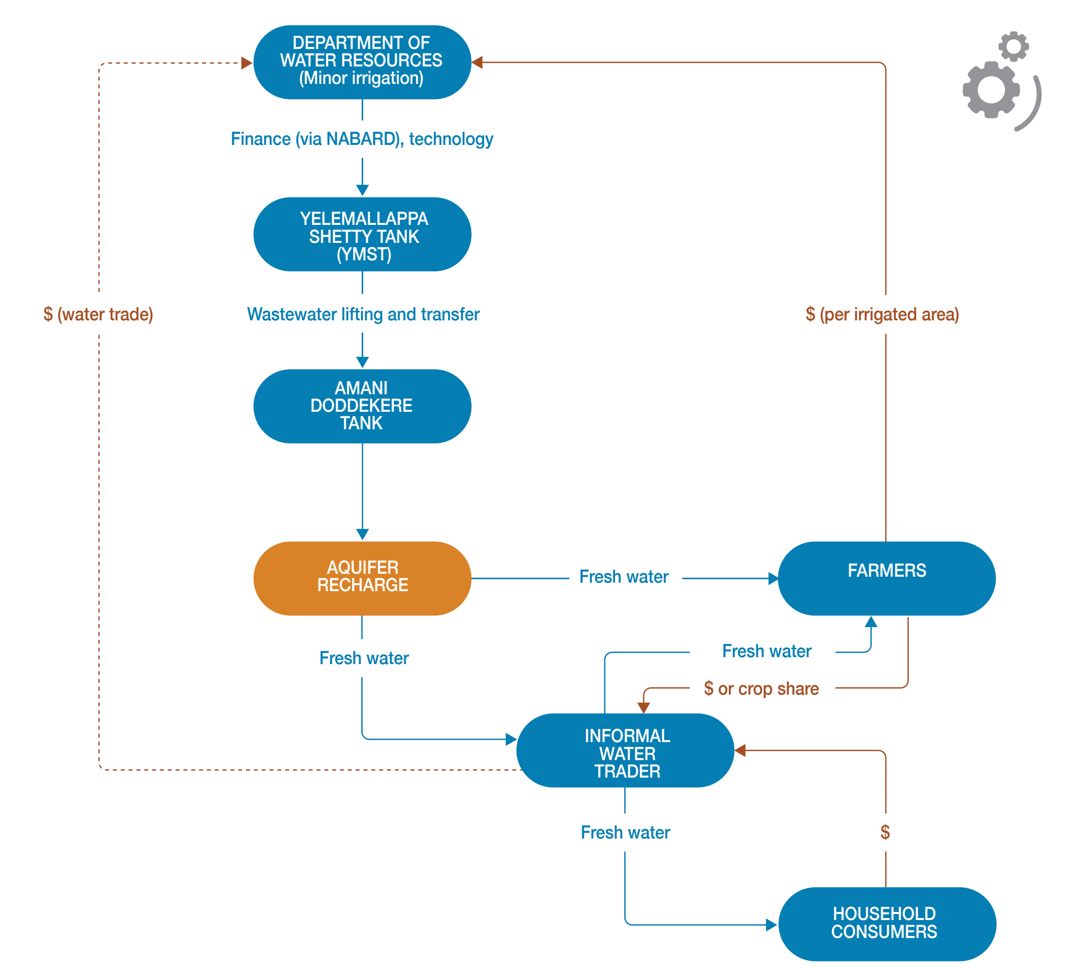
SOCIAL & ENVIRONMENTAL BENEFITS

- Increase in irrigated farming, crop yield and food security
- Increase in tank biodiversity (flora and fauna) and related activities (e.g. bird watching)
- Private sector support (water vendors)
- Recharge of municipal wells for drinking water supply
- Livestock support through irrigated fodder production

Although water reuse is encouraged, questions around the ownership of the wastewater vis-à-vis the recharged groundwater, and the modalities for institutions to charge for groundwater abstraction remain subjects of discussion. The situation is complex as small farmers who are charged per irrigated area take advantage of their aquifers for selling water to tanker operators. Also in Bangalore and its vicinity private water supply is rampant filling gaps in the public supply system, while legislations to limit groundwater abstraction are hard to implement, especially where farmers can make easier money from selling water than via irrigation.

A 'larger' institutional challenge of the water transfer is that the river basin is shared by the states of Karnataka and Tamil Nadu. There are strong objections by the state of Tamil Nadu over Karnataka building permanent structure to divert water for its own needs while Tamil Nadu continues suffering from water scarcity. Thus, initiating any project even to utilize the wastewater for any existing tank command area needs clearance from the Central Water Commission.

FIGURE 257. BUSINESS PROCESS FLOW (WATER RELATED)



The YMST lift irrigation scheme is one of several planned lake-to-lake inter-sectorial water transfers around Bangalore, for which models for institutional collaboration and ownership have been described (ICRA, 2012).

Technology and processes

Aside the initial lift pumping, the technology is based on physical, chemical and biological processes of natural water treatment (sedimentation, filtration, sun exposure, etc.) above and below ground along the 20 km water passage into the YMST, and between YMST and Hoskote. The potential of natural water treatment should in this context neither be over- nor underestimated. In the current case, the 6.2 km long wastewater overland transfer after leaving the YMST occurs partly piped, partly open, before the water enters the Amani Doddekere tank and gets filtered while percolating through 200 meters of rock to reach the groundwater table. About half of the passage requires pumping, half follows gravity flow. The water is not running continuously as pumping is sometimes stopped over hours or days. While the recharged groundwater at Hoskote appears to be of excellent (potable) quality, as tested by the BMS College of Engineering, Bangalore, any change in transport distance, groundwater table, type

of rock, etc. can influence the final water quality. Therefore, water quality monitoring is important, also as there are no data how the natural treatment will continue over the years. To minimize health risks, other planned water transfer schemes around Bangalore recommend wastewater treatment before the final reservoir (ICRA, 2012).

Funding and financial outlook

The financial cost estimate for the YMST lift irrigation system was USD 579,000 with financing from National Bank for Agriculture and Rural Development (NABARD). The actual cost incurred, including additional works was USD 674,000. Charges for irrigation are marginal, about USD 2.6/season/ha for horticulture and floriculture, with free electricity for pumping groundwater.

The Department bears the operation and maintenance cost of at least USD 3,000 per month. Current irrigation water charges for horticultural crops (ca. USD 5.4/ha/yr) generate maximal USD 930 per year, or 2–3% of the annual O&M costs if all transferred water will end on farms which are charged and not be lost/redirected on the way to Hoskote. These charges are much lower than what farmers are willing to pay, which could cover up to 25% of the ongoing operation and maintenance costs as shown by IWMI in the Hoskote area (Scharnowski, 2013). Applying water charges to other users, especially water vendors, will be difficult as the market is informal and hard to monitor. However, for the success of the project, the present policy framework (the 2003 guidelines for lift irrigation) estimates the project benefits through the achieved agricultural yield increase, not through financial cost recovery.

Socio-economic, health and environmental impact

Due to surface water scarcity, groundwater access is most crucial around Bangalore. Nearly 99% of all farmers in rural Bangalore depend on tube wells. The water transfer allows farmers now to cultivate more land or more than one crop per year, or crops with a higher return on the urban market. According to local media, the water table in about 30 villages surrounding Hoskote has increased to the benefit of up to 500 farmers.[10]

The situation also improved water supply to households in Hoskote Municipality which had before the scheme only water for once a day to once in ten days for few hours. Now, up to 60,000 inhabitants are reported as beneficiaries, either directly via own borewells or indirectly via local water vendors (tankers). Improved water access is in particular helping women, given the gendered nature of water collection (Borthakur, 2015).

Also dairy development is among the benefits of the project due to the increased availability of fodder from the wastewater reuse. The 'new' water in the tank revived local fish farming and lured various species of birds to the revived wetland, creating a regional hot spot for birding.[11]

The positive impacts could also extend to the YMST if the lifting of larger water volumes for Hoskote and other lakes could be realized. However, aside some initial groundwater testing, neither, soil, water, crop or fish quality is being monitored, and health risks are high, especially as farmers (without well) might use the wastewater directly, and not via groundwater as seen at other polluted lakes. Safeguards are also needed to ensure that possible negative long-term impacts are under control.

Scalability and replicability considerations

The key drivers for the business model are:

- Water scarcity and high water demand catalyzing public investments.
- Strong policy support for lake conservation and development.

As both drivers are omnipresent in the region, already other lift irrigation schemes for water transfer are under discussion such as for replenishing 29 minor tanks around Chikkaballapur and Hoskote towns, using in this case treated wastewater. As part of an IWRM strategy for Bangalore, McKinzie and CII (2014) proposed a programme of lake regeneration to improve urban groundwater supply. Starting with 38 lakes, each one should be linked to a sewage treatment plant to clean lake inflow. These 38 lakes could increase Bangalore's water availability by an estimated 180 MLD. A comprehensive tank rejuvenation project was undertaken for example for the Jakkur Lake in the northern part of Bangalore at the cost of Indian Rupees 215 million (USD 3.37 million). The lake was dewatered, de-silted and all sewage inflows were diverted to a 10 MLD sewage treatment plant. The treated wastewater flows then through a constructed wetland before entering the lake itself. The result has been an increase in biodiversity, fishing and groundwater recharge (Evans, 2016).

While the use of wastewater for lake regeneration and aquifer recharge has been accepted in the case of Hoskote and shows favorable environmental and economic benefits, this does not have to be the case in other locations as water quality varies significantly and so the risks and public acceptance of indirect wastewater use is also not universal. Therefore, full stakeholder participation and information appear as important as water quality monitoring. Stakeholder inclusion is also needed for the discussion of options for cost recovery from the various beneficiaries, and modalities on how to address illegal water abstraction from the transfer canals.

For any replication of the reuse model, in particular in Karnataka, a legal and institutional framework with clear responsibilities would be beneficial. The same will be an institutional challenge in many other regions, given that such a water transfer links multiple sectors, i.e. urban and rural authorities in charge of surface and groundwater, sanitation, health, drinking water and agriculture. Regulations are also required to prevent that lift irrigation schemes eventually harm agriculture because of farmers becoming water vendors. In recent years, there has been a surge in the conversion of agricultural wells on the outskirts of Bangalore to supply urban consumers because agriculture is less profitable than selling water (and businesses can profit from the subsidized electricity afforded to rural landowners).

The resulting water loop appears to reflect an increasing reality of the circular economy between urban and rural areas in India, where the urban hinterland functions as a 'kidney' for urban water reuse.

Summary assessment – SWOT analysis

The business case focuses on mitigating the economic impact of water scarcity by providing water to farmers for irrigation through the use of (waste)water for groundwater recharge. Additional benefits were observed for household water supply and ecosystem services. Taking advantage of natural water treatment processes, the city saves on treatment and disposal cost for wastewater while farmers and others benefit from 'new' water for their economic activities. There are also substantial benefits for the informal water market through the sale of groundwater to farmers, industry and households. The observed and largely praised success of the project could have even been larger as a significant water volume got lost due to illegal wastewater extraction before the water reached the targeted ADT. There are various options for revenue generation from different beneficiaries who would pay for a reliable water supply. However, already the significant welfare benefits and their downstream impacts on regional economic performance make this social business highly worthwhile.

A long term impact on groundwater quality can be expected, and close water quality monitoring is highly recommended. A better alternative would be to treat all water entering the YMST. Another challenge will be to steer the right hydrological balance between formal aquifer recharge and formal and informal water extraction. Figure 258 shows the SWOT analysis for this business case example.

FIGURE 258. SWOT ANALYSIS OF BANGALORE GROUNDWATER RECHARGE, INDIA

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Strong policy support for tank rehabilitation and protection ▪ Governmental support of lift irrigation for groundwater recharge ▪ High demand for (waste)water ▪ Recharged ground water suitable for drinking purpose ▪ High economic and ecosystem service benefits, making the system worthwhile without cost recovery	**WEAKNESSES** ▪ User participation was limited to farmers ▪ Unexpected wastewater diversion along the water passage to Hoskote not covered in any EIA ▪ Insufficient water quality monitoring ▪ As the system is not designed for cost recovery, rigorous options to monitor and regulate water abstraction are missing
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Potential to establish clientele/ revenue relationship with various water users, beyond farmers ▪ Value of wastewater (farmers, water suppliers through tankers and local bodies) 3 to 12 times higher than the current water charges	**THREATS** ▪ Conflicts with Tamil Nadu over water infrastructure could stall replication of the model ▪ Aquifer pollution risks resulting in health issues for farmers and other water users, unless YMST water gets treated ▪ Lift irrigation might serve more sale of drinking water than agriculture and eventually result in farmers stop farming

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Case descriptions are based on primary and secondary data provided by case operators, local insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2013–2015. As business operations are dynamic data are likely subject to change.

Notes

1 Also spelled Hosakote.
2 In South Asia, the term ‘tank’ is used for man-made water reservoirs (lakes) which are often centuries-old, constructed for rain/surface water storage, mostly for irrigation but also other community needs. Several tanks can be interconected.
3 Groundwater overexploitation at Hoskote is reported as 144%. http://timesofindia.indiatimes.com/city/bangalore/Water-table-in-Bangalore-South-drying-up/articleshow/7838020.cms?referral=PM (accessed 4 Nov. 2017).
4 http://reliefweb.int/report/india/drought-hit-karnataka-regulates-borewells (accessed 4 Nov. 2017).
5 Observation during field work in 2012.
6 www.deccanherald.com/content/244394/tn-now-lays-claim-city.html (accessed 4 Nov. 2017).
7 This would require that those farmers who are illegally tapping into the water transfer will be charged. In fact, the Department of Minor Irrigation and Revenue Department are not charging farmers of the ADT, firstly as the tank was for nearly two decades dry and farmers invested big money on tube wells, and even the ‘new’ water pumped from YMST has not risen above the sluice level to carry water in the irrigation channels.
8 Tube well owners expressed their willingness to support the water transfer with a monthly rate, as they see a clear relation between tank water level and tube wells, usually with four to five days of delay. A revenue system for tanker operators could be based on number of tankers and their volumes (usually 4,000–6,000 liters), while neither actual pumping (tanker filling) nor water delivery are easy to monitor.
9 http://timesofindia.indiatimes.com/city/bengaluru/Depleting-water-table-could-hit-city-outskirts-hard/articleshow/50665373.cms (accessed 4 Nov. 2017).
10 www.deccanherald.com/content/227529/hoskote-reuses-bangalores-refuse-ends.html (accessed 4 Nov. 2017).
11 As the lake is, with its about 940 ha, rather large, the water inflow creates a patchwork of grassland and water bodies ideal for many kinds of birds.

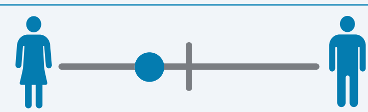
BUSINESS MODEL 21

Cities as their own downstream user

(Towards managed aquifer recharge)

Munir A. Hanjra and Pay Drechsel

Key characteristics

Model name	Cities as their own downstream user
Waste stream	Treated and partially treated wastewater recharging local aquifers
Value-added waste product	Reclaimed groundwater for domestic and agricultural use
Geography	Water stressed urban areas with suitable peri-urban conditions for aquifer recharge
Scale of production	Medium to very large (depending on aquifer characteristics and urban demand)
Supporting cases in the book	Mexico City, Mexico; Bangalore, India
Objective of entity	Cost-recovery [ ]; For profit [ ]; Social enterprise [X]
Investment cost range	Depending on wastewater volume and scale from USD 500,000 to 700 million for wastewater treatment and conveyance (the water recovery from the aquifer will only be a fraction of this)
Organization type	Public, public-private, or mixed formal/informal sector arrangements
Socio-economic impact	Increased water security, reduced treatment costs, supported ecosystem services, but also health risks for farmers and urban consumers depending on final water quality
Gender equity	Beneficial to women and children due to increased water security and time savings for accessing water 

Business value chain

The model builds on the common trajectory of cities that are addressing growing water demand by first exploiting urban ground- and surface-water resources, and then start tapping into peri-urban and rural water resources while releasing all the time their wastewater into the urban periphery. Over time, surface and groundwater reservoirs in urban proximity become increasingly dependent on the urban return flow, making cities eventually their own downstream user. As there are multiple sources for water supply and possibilities for wastewater release, the city can turn this usually unplanned development into a development effort to a) target particularly suffering peri-urban areas for groundwater replenishment; and/or b) particular aquifers for underground storage serving the city itself.

The aquifer replenishing capacity can be remarkable as the two cases from India and Mexico showed. The two cases are, however, only examples of a diverse set of surface-groundwater interactions taking place in an increasing number of rural-urban corridors in low-income countries. Common characteristics are missing institutional responsibilities, limited water quality monitoring and wastewater treatment, and an increasing dependency of urban water supply on informal water markets. As mentioned in

the model introduction, the presented cases are thus not success stories according to best practices and standards, as presented by Lazarova et al. (2013) but reflect situations and challenges on the trajectory to a more planned and managed aquifer recharge (Jiménez, 2014). To build on the positive potential of the cases, Model 21 has to emphasize risk management. The same applies to informal wastewater irrigation in the following Models 22 to 24.

The business concept is to turn the need for waste disposal, with its related costs and potential environmental hazards, into an opportunity to generate 'new' water in water scarce environments, which allows generating revenue from the value that water has to farmers and other users (Figure 259). The concept builds on the potential of managed aquifer recharge to maximize social and economic benefits including the protection of public health. The business concept can be implemented by public water/wastewater utilities, or in public-private partnership. The model acknowledges that conventional wastewater treatment in most low-income countries will in the short and medium term not be able to treat all urban wastewater to the standards needed for irrigation and/or domestic use. It builds therefore on the cost-saving additional treatment capacity of natural processes taking place during wastewater conveyance in open channels and infiltration in the soil for (deep) aquifer recharge. Part of the wastewater stored in aquifers can be retained for longer periods during wet years and used in drier years, to supply – depending on the achieved water quality – water to those users (domestic, farmers) who would otherwise face water scarcity challenges.

As the case studies showed, the urban return flow can with time constitute a major share in the local aquifer. Among several monitoring needs, a particular challenge for controlling water withdrawal and quality, concerns the informal water sector, which is usually accessing the aquifer for community water supply in a non-transparent manner. A related challenge is how far these commercial water traders could be charged for the volume of water they are abstracting as the water volumes are difficult to monitor. Moreover, the private sector would probably try to recover any abstraction fees from the served households, which would further disadvantage the poor depending on the informal sector.

Business model

The business model tries to support in dry climates peri-urban and rural areas with depleted aquifers by channelling the urban return flow to unlined reservoirs, forest plantations, etc. for targeted aquifer recharge. Depending on wastewater quality, the model provides a set of benefits:

- Costs for additional treatment or water disposal can be avoided.
- With restrictions, also farmland or forests can be used for aquifer recharge while providing water and nutrients, e.g. to fodder crops and ornamentals.
- Replenished aquifers can support local and urban water needs and economies, including small industries and irrigated crop production.
- Support of ecosystem services and biodiversity in dried-up reservoirs turned wetlands.

In case that also farms are used for aquifer recharge, farming and irrigation practices must follow appropriate safety guidelines and be such that they facilitate water infiltration (e.g. high irrigation rate in the area, storage and transport of wastewater in unlined dams and channels), and the underground suitable for water treatment (supportive soil texture and geo-hydrological conditions).

With most direct revenues deriving from the sale of 'reclaimed' waste/groundwater to urban and industrial users (Figure 260), a positive benefit-cost ratio could be expected if avoided costs are considered, like for wastewater treatment, storage or obtaining water from other sources (Perrone and Merri Rohde, 2016; Vanderzalm et al., 2015). As shown from those cases of managed aquifer recharge, any additional environmental and social benefits will help outweighing costs. A main incentive for this

FIGURE 259. SIMPLIFIED VALUE CHAIN WITH ONLY ONE URBAN AND RURAL UTILITY REPRESENTING POTENTIALLY MORE PUBLIC ENTITIES ENGAGED IN THE MANAGEMENT OF WATER AND (TREATED) WASTEWATER FOR GROUNDWATER RECHARGE FOR REUSE

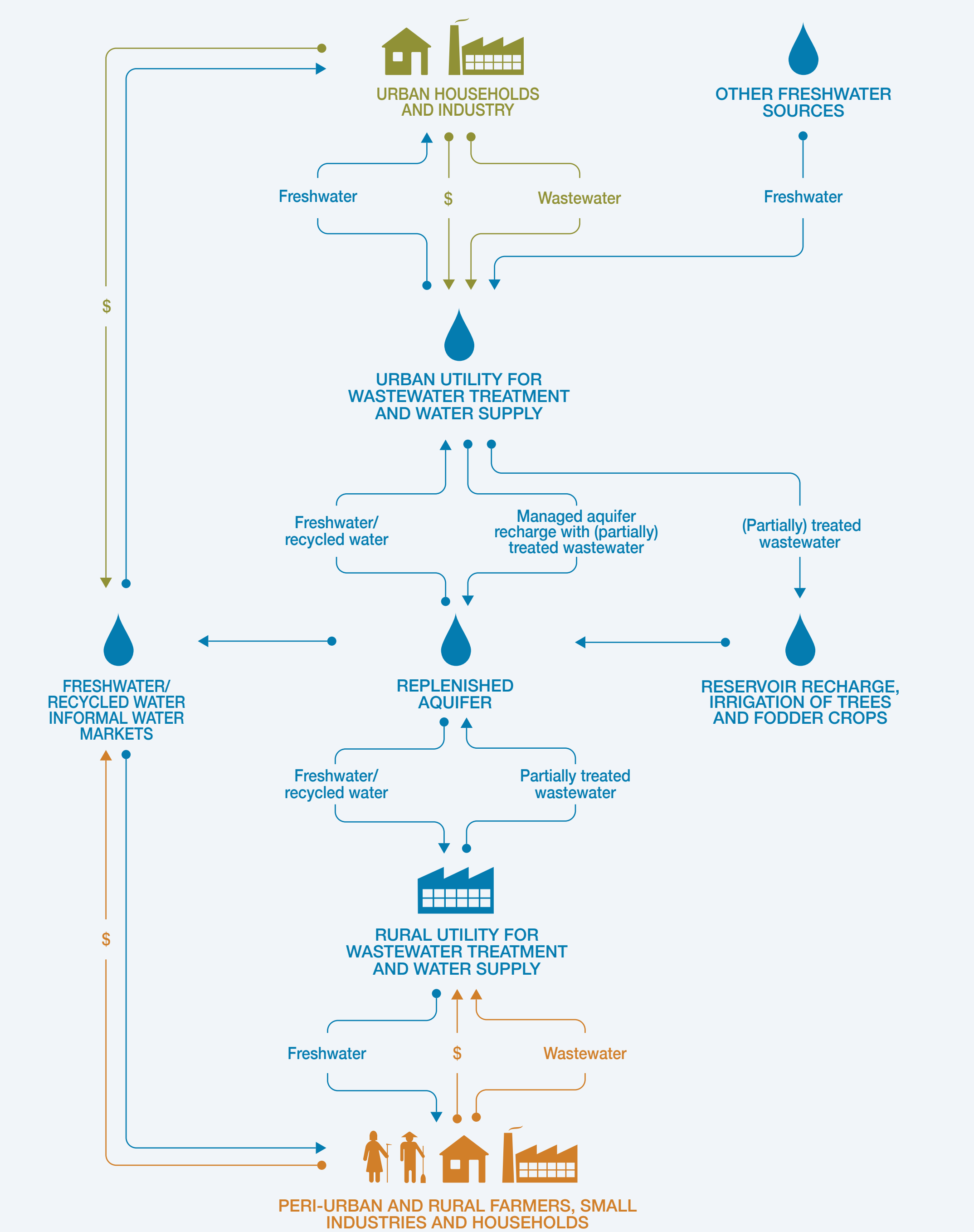


FIGURE 260. BUSINESS MODEL CANVAS FROM THE PERSPECTIVE OF THE MAIN PUBLIC UTILITY RESPONSIBLE FOR WASTEWATER MANAGEMENT IN THE CASE OF AQUIFER RECHARGE AND REUSE

KEY PARTNERS

- Community representatives from recharge area
- Other urban and rural water utilities and operators (health, agriculture, geology, . . .)
- Private (informal) water market

KEY ACTIVITIES

- Managing wastewater (treatment, conveyance)
- Selling treated wastewater and freshwater/ groundwater
- Aquifer management and water quality control

KEY RESOURCES

- Land with hydro-geological conditions suitable for water treatment and aquifer recharge
- Treatment plants and water conveyance infrastructure/ capital
- Aquifer management expertise

VALUE PROPOSITIONS

- Improving the cross-seasonal access to water for irrigation and domestic needs through underground storage and reuse of treated wastewater

CUSTOMER RELATIONSHIPS

- Formal water allocation contracts

CHANNELS

- Automatic billing
- Water transfer through pipes and canals
- Stakeholder platform

CUSTOMER SEGMENTS

- Households and farmers in rural, peri-urban and urban areas in need of water

COST STRUCTURE

- Wastewater treatment
- Water pumping for transfer and withdrawal
- Water quality monitoring

REVENUE STREAMS

- Sale of freshwater including reclaimed water from the aquifer
- Savings in potable water access from alternative sources
- Savings in wastewater treatment

SOCIAL & ENVIRONMENTAL COSTS

- Possible health risks/costs from insufficiently treated wastewater
- Possible soil contamination through long term wastewater infiltration

SOCIAL & ENVIRONMENTAL BENEFITS

- Increased water and food security
- Economic stability also in dry seasons and under climate change
- Reduced impact of water stress levels on livelihoods
- Ecosystem service support

social business model, like in the water swap model (Chapter 17, Business Model 20), should however be the potential costs for the society at large under extended periods of droughts as well as the costs of possible epidemics in the business-as-usual situation vis-à-vis investments in quality monitoring.

Thus, to propose a sustainable model, possible health hazards have to be controlled. This requires clear institutional responsibilities and regulations across the rural-urban boundary, the common administrative freshwater – sanitation divide, and acknowledgement of informal water markets to start a dialog on 'best practices'. All of this constitutes in many low-income countries significant challenges in need of multi-stakeholder platforms (Londhe et al., 2004; Foster et al., 2010; Foster and Vairavamoorthy, 2013; Yuan et al., 2016).

Potential risks and mitigation

In designing any optimized business model based on case studies, it is assumed that generic business risks are known and will be taken care of. However, some risks might be more model specific and will be acknowledged in the following:

Market risks: The market risk is small as long as no other water sources are available cheaply for farmers or households and groundwater ownership is clearly defined, allowing the utility to charge for water use or sell water entitlements. Market risk may however arise due to risks associated with the use of unsafe water, and customers losing trust in the replenished groundwater. The informal water market is likely to take advantage of the replenished aquifer (even with farmers entering the water trade) and its water withdrawal requires regulations and innovative ways of monitoring.

Competition risks: A risk could arise if the water receiving households or farmers get in seasons of high water demands access to a cheaper alternative water source. This is however unlikely as any additional water would also be sold by the same utility and the informal market sells at higher prices than the utility. There could be competition between sectors within the same community if for whatever reason the wastewater transfer is interrupted and so the aquifer supply. In this case, municipalities might compete against farmers to acquire their groundwater abstraction rights to harness the economic benefits and revenue gains that the business model offers to domestic and industrial users.

Technological risk: There seems to be limited risk due to the low-technology status as long as land is available, and the recharge is based on hydro-geological feasibility and environmental impact assessments.

Political and regulatory risks: The business requires a) well defined groundwater and wastewater related water rights or entitlements; b) reuse guidelines based on water quality; and c) monitoring mechanisms related to both requirements. Building on the currently available global water reuse regulations and guidelines for MAR with reclaimed water, a standardized approach should be developed and can be used by regulatory agencies, municipalities, and other water providers if their own regulatory framework is inadequate, as suggested e.g. by Yuan et al. (2016).

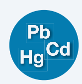
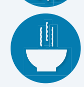
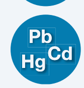
Social equity related risks: Like the other rural–urban water exchange model, the model links different interest groups in need of water, and this across administrative boundaries and sectors and thus needs an inclusive process of planning and implementation where all parties can express their interests during fair contract negotiations.

The additional availability of water is considered a particular advantage for women in charge of water acquisition with multiple social and health benefits.

Safety, environmental and health risks: The health risks connected to this business model depend strongly on the treatment in place, before and after aquifer recharge. Given the interaction of wastewater and drinking water, the WHO *Water Safety Planning* and *Sanitation Safety Planning* manuals could be applied, but also guidelines particularly developed for aquifer recharge (Yuan et al., 2016). The latter also applies to environmental protection and long-term accumulation of contaminants in the soil. When sound regulations are in place, managed aquifer recharge can be safe and offer simple, low-tech and cost-effective treatment systems for developing countries.

The address possible safety and health risks, standard safety precautions should be applied to water withdrawn from the recharged aquifer (Table 60).

TABLE 60. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 21

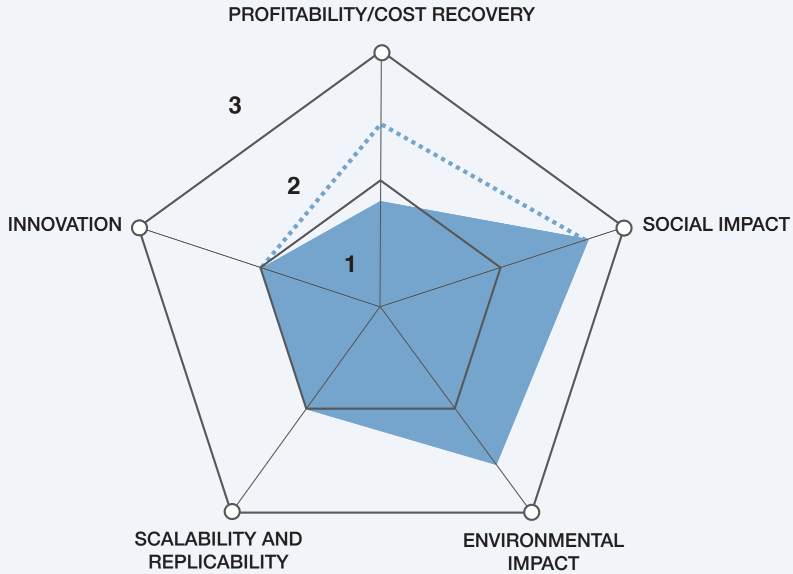
RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR/ ODOR	INSECTS	AQUIFER/ SOIL	RECLAIMED WATER	
Community	MEDIUM RISK	MEDIUM RISK	MEDIUM RISK	HIGH RISK	NOT APPLICABLE	Multi-barrier approach recommended and application of WHO's *Water and Sanitation Safety Planning* manuals (WHO 2009, 2015)
Farmer	LOW RISK	LOW RISK	MEDIUM RISK	HIGH RISK	NOT APPLICABLE	
Consumer	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE	MEDIUM RISK	
Mitigation measures		 			  	

Key: NOT APPLICABLE, LOW RISK, MEDIUM RISK, HIGH RISK

Business performance

This model ranks highest on **social impacts** as the reuse of wastewater for domestic supply and crop production offers significant benefits to urban consumers and agricultural communities as long as safety requirements are met. While in water scarce regions the model will probably be profitable compared to alternative options, its larger benefits are the prevention of drought related costs for the society at large, which can exceed the investment costs multiple times. While there are several plans for replicating the Indian **case** at other locations around Bangalore, it will require clear institutional mandates and regulations to implement the required safety monitoring system for human and environmental health. Assuming these are in place, also possible ecosystem benefits can become substantial (Figure 261).

FIGURE 261. RANKING RESULTS FOR GROUNDWATER RECHARGE MODEL USING UNTREATED WASTEWATER WITH LIKELY VARIATIONS IN COST RECOVERY (DOTTED LINE)



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18. BUSINESS MODELS FOR INCREASING SAFETY IN INFORMAL WASTEWATER IRRIGATION

Introduction

The challenge in view of wastewater reuse is not only to increase the reuse of **treated** wastewater as targeted for example in SDG 6.3, but to make the already ongoing informal irrigation which is on millions of hectares directly or indirectly using **untreated** wastewater safer. Untreated wastewater is released in large volumes across the developing world into rivers, used for irrigation purposes. The indirect reuse of this water for crop production, like any direct wastewater use, allows water-borne diseases which affect farmers in the field to turn into food-borne diseases affecting consumers, with a potentially significant economic impact. This informal wastewater reuse sector which support millions of livelihoods in and around four of five cities in the developing world occupies about 30 times the area than the one in our records where treated wastewater is used (Scott et al., 2010; Thebo et al., 2017). There is a significant need for business models to move from informal to formal reuse, despite inability of most developing countries to progress as fast as needed with wastewater collection, treatment capacity, or ability to enforce regulations.

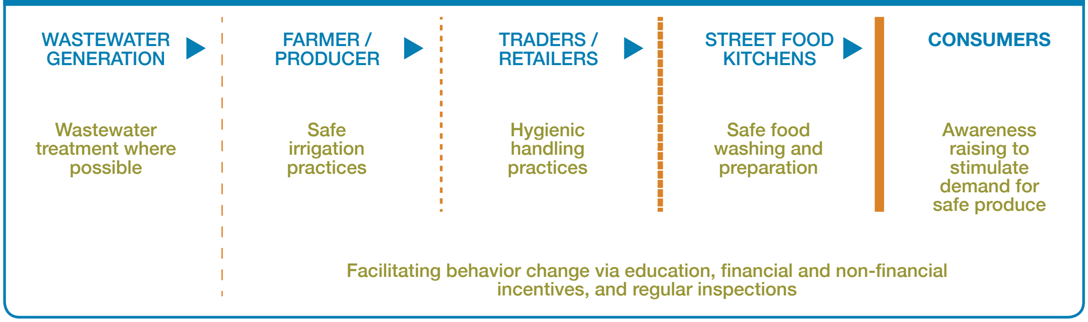
Informal reuse of wastewater is a booming economic activity that benefits farmers and irrigators privately and also the local economies and food supply, but also entails significant health costs, mostly borne by the public. The **social** nature of these costs justifies public investments in incentives to promote safe reuse of wastewater and minimize risk along the entire value chain to turn this **unsafe** informal activity into a **safe** and formal one with shared rewards for all the stakeholders. But how to finance such investments where public budgets cannot keep pace with population growth and wastewater generation?

Examples of answers are provided in a set of different business models which are (like all models in this catalogue) based on empirical cases. The variety represents regionally different drivers and pathways to catalyze individual or institutional behavior change from informal to formal reuse (Saldias, 2016). The change can be based on direct or indirect incentives, increased risk awareness or on a dialog between key stakeholders on their needs, the analysis of costs and benefits and business contract. Another pathway is to seek technical synergies between private and public interests, and where the public sector has limited capacity or resources to engage, also the private sector can offer the incentives needed for behavior change. In all these cases, the value proposition is increased food and occupational safety. Investments in these business models can save USD 5 in consumer health care for every dollar spent on risk reduction from 'farm to fork' (Drechsel and Seidu, 2011; Keraita et al., 2015).

While the benefits outweigh the costs, risk awareness and the incidence of costs and benefits do not fall evenly across stakeholders along the value chain and this creates difficulty for incentive design and financing the investment. In other words, not all who could change the game might directly benefit from this, or understand the need for change. In this context it is for example important to distinguish between the direct reuse of raw, undiluted wastewater and the much more common indirect reuse. Direct reuse is usually a planned activity where farmers lack alternative water sources and/or seek the nutrient value of the water. In contrast, the indirect use of wastewater after it got mixed with other water sources is usually not driven by farmers' interest in wastewater, but simply in water. How far farmers experience and realize water pollution depends on the degree of wastewater dilution. As a result, many farmers would not consider themselves as wastewater users and also do not see anything wrong in their professional activities, in contrast to scientific risk assessments (Keraita et al., 2010).

The limited risk awareness is an important factor for the implementation of risk mitigation strategies, and calls for a mix of approaches with financial, regulatory as well as social incentives and awareness creation to support behavior change (Drechsel and Karg, 2013). From a technical perspective, there are many low-cost options available which can on their own or better in combination significantly reduce the risks on- and off-farm especially from pathogens. Such a multi-barrier approach is fully supported by the WHO (Figure 262). However, given the missing direct incentives and risk awareness of those who should implement these safety measures, they have to be easily adoptable, low-cost but highly cost-effective (Drechsel and Seidu, 2011).

FIGURE 262. THE WHO PROMOTED MULTI-BARRIER APPROACH TO REDUCE HEALTH RISKS WITH AND WITHOUT WASTEWATER TREATMENT



Source: Amoah et al., 2011. The approach is based on the Hazard Analysis and Critical Control Point (HACCP) concept.

The informal irrigation sector where the use of wastewater or polluted water is common in and around four of five cities in the global South, shows a mosaic of situation and business model and multiple pathways towards formally recognized and supported wastewater use (Raschid-Sally and Jayakody, 2008).

Variations exist in terms of water quality, i.e. level of treatment or dilution, scale of use, water access, related costs/fees, market penetration, risk awareness along the value chain, enforcement of safety measures, etc. In most cases of indirect use, i.e. where wastewater and freshwater are mixed, the water is perceived as a natural and allocated to framers according to freshwater rules. Where farmers use raw wastewater they might pay a fee for the water, which is usually lower than the one they would pay for freshwater, or their rent for land with access to wastewater is higher than of land without water access, or the wastewater user rights might be auctioned to farmer groups.

Among the multitude of cases and situations in the informal reuse sector, three types were selected where different drivers support change towards a higher degree of safety. The three cases/models are each presented as **hybrids** (case-cum-model) as there would be too much overlap if presented separately. The three show options how the informal use of wastewater (be it polluted fresh water or diluted or raw wastewater) could become safer even under the common circumstances of missing treatment capacities and unenforced or absent water reuse regulations and standards:

a) **Business Model 22** is based mostly on examples from Ghana and shows how private sector driven corporate social responsibility (CSR) initiatives can be a driver of change, in particular in the informal food supply sector.
b) **Business Model 23** is based on examples from Pakistan and India. It shows how contractual agreements allow turning informal reuse into formal reuse, with the potential to introduce safety measures. In this example, wastewater is auctioned to farmer associations.

c) **Business Model 24** is based on a case from Southern Ghana. It shows options on how farmers' investments in low-cost infrastructure to access and store water can be combined with the WHO promoted multi-barrier approach, i.e. using farmers' innovation capacity to support reuse safety. Farmers' innovation capacity is well known (Reij and Waters-Bayer, 2001) and has been reported also from other countries where wastewater irrigation is common (Buechler and Mekala, 2005).

A model with focus on improving the safety of informal (sludge) reuse which combines elements from Models 23 and 24 was presented in the Nutrient Recovery section (Business Model 15).

Many variations of these models are possible and can be supported through various incentives such as land security, training, certification schemes for safe farming, access to loans or subsidies etc. Assistance is also needed in view of compliance monitoring as farmers will not be able to finance water or produce analysis for comparison with safety standards. The WHO supported *Sanitation Safety Planning* manual (WHO, 2015) will be a useful guidance document in this situation.

Our three examples are not exhaustive. There are other options, especially where with increased wastewater treatment and enforced regulations wastewater use became a business sector on its own. For an analysis of possible trajectories from informal to formal water reuse, see Saldias (2016) and for success stories from the formal reuse sector, for example, Lazarova et al. (2013).

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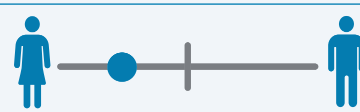
BUSINESS MODEL 22

Corporate Social Responsibility (CSR) as driver of change

Pay Drechsel

Key Characteristics

	**Model name**	Corporate Social Responsibility as driver of change
	Location of supporting cases	Ghana (with additional input from other countries)
	Waste stream	Wastewater, partially treated or untreated but often diluted
	Value offer	Safe food at point of consumption (target)
	Geography	Informal irrigation sector in the global south using unsafe wastewater in semi-arid to humid regions
	Scale of production	Small to Medium (at farm level: 100 to 1,000+ farmers per city irrigating usually raw eaten leafy greens)
	Supporting cases in the book	This model is in its presentation a hybrid of case and model, and builds on observation in particular in Ghana and Pakistan, but also southern Africa and India
	Objective of intervention	Cost savings [ ]; Cost-recovery [ ]; For profit [X]; Social enterprise [X]
	Investment cost range	USD 900,000 (for 2,000 farmers), USD 1,400,000 (for 5,000 street kitchens) in the example Ghana's top 5 cities
	Organization type	Private sector
	Major partners in the case example	Stakeholders along the farm to fork value chain, local and international private sector
	Socio-economic impact	Each USD invested in on- and off-farm risk reduction saves USD 4.9 in public health costs
Gender equity	**CSR interventions strongly support women and inclusiveness**	

Business value chain

A major social challenge are public health risks from the very common use of untreated wastewater in the informal irrigation sector of most low- and middle-income countries (Box 12). Many success stories on the trajectory from informal to formal reuse come from countries which succeeded in enhancing their treatment capacities and enforcing crop restriction, either as a result of epidemics or supported by high public risk awareness, such as in Israel, Chile, Jordan, Tunisia or Mauritius (Saldias, 2016). However, where capacities for wastewater treatment or the enforcements of crop restrictions are

missing or only emerging, and also public risk perceptions are low, alternative strategies are needed for successful interventions in the usually highly profitable (wastewater) irrigation business.

In this situation, where the public sector is facing its limits, private sector driven corporate responsibility models can play an important role, and support occupational and consumer safety.

As discussed in Chapter 1, corporate responsibility can have different levels of buy-in, and even where environment values have been adopted, CSR drivers can range between 'selfish' investments in resource and cost efficiency to investments in longevity of the business in its protected environment:

> Corporate social responsibility (CSR) refers to business practices involving initiatives that benefit society. A business's CSR can encompass a wide variety of tactics, from giving away a portion of a company's proceeds to charity, to implementing "greener" business operations.[1]

The here presented model for improved water quality and food safety remains in large still hypothetical but is based on promising examples found in Western and Southern Africa as well as Pakistan. The model is highly compatible with the multi-barrier approach promoted by WHO in its 2006 wastewater reuse guidelines and further developed in the *Sanitation Safety Planning Manual* (WHO, 2006, 2015). However, the model is not an end in itself as it largely depends on behavior change and has to be supported by educational and regulatory measures to achieve its potential.

Box 12. The challenge of informal wastewater use

Reuse of raw or diluted wastewater for irrigation of field crops is practiced around most cities of the global South on a total area of up to 35 million hectares (Raschid-Sally and Jayakody, 2008; Thebo et al., 2017). Most of this irrigation is using untreated or at best partially treated wastewater, at a thirty times larger scale than the known areas using treated wastewater (Scott et al., 2010); Thebo et al., 2017.

This informal wastewater use is probably the most common 'business model' of resource recovery and reuse where waste is turned directly into an asset, however, without the required treatment to assure occupational safety or protect consumers of irrigated produce. The practice spreads without facilitation, driven by a reliable water supply and high demand for irrigated cash crops from growing urban markets, a demand which can lift farmers out of poverty (Drechsel et al., 2006). Where the wastewater is raw, farmers might also appreciate its nutrient content; while in those locations where it is diluted, farmers might not know about the invisible risks of their water source for human health and the environment (WHO, 2006).

As informal wastewater reuse flourishes especially in low-income countries where not only wastewater treatment capacities are limited, but also regulations weak and banning of wastewater irrigation neither practical nor feasible, the challenge is how to implement safety measures in this situation. From a technical perspective, there are many low-cost options available for on-farm and post-harvest risk reduction which can on their own or ideally in combination (multi-barrier approach) significantly reduce health risks for farmers and consumers, especially from pathogens. However, due to low risk awareness in the population there is limited market demand and financial incentive for safety measures. A high adoption rate is however required for any larger impact and cost-effectiveness (Drechsel and Seidu, 2011).

Business model

Among different drivers of CSR, the here presented canvas has the focus on increasing product safety as value proposition (Figure 263). Protecting public health within and beyond the food chain can take place at different risk barriers, like (a) wastewater treatment, (b) on-farm, and (c) in the post-harvest and food processing sector as supported internationally by the Hazard Analysis and Critical Control Points (HACCP) concept. Some options related to the interface of water quality and reuse are illustrated below.

FIGURE 263. BUSINESS MODEL CANVAS – CORPORATE RESPONSIBILITY MODEL

KEY PARTNERS

- Farmers
- Traders
- Street food kitchens
- Regulators
- Media
- Public sector
- Social marketing institute
- Certification offices

KEY ACTIVITIES

- Customer training
- Customer support
- Awareness creation
- Product placement
- Branding
- Monitoring

KEY RESOURCES

- Company resources
- Research on options for behavior change
- Knowledge about safety options

VALUE PROPOSITIONS

- Product safety for farmers, traders and consumers

CUSTOMER RELATIONSHIPS

- Indirect (training of trainers) and direct communication and interaction with farmers and traders through training workshops and in the field, and consumers via different media
- PPP with public sector

CHANNELS

- Workshops
- Company initiated customer associations
- Advertisements
- Media

CUSTOMER SEGMENTS

- Farmers and traders using so far unsafe water and/or unsafe food production practices
- Consumers of food
- Public sector concerned about food safety

COST STRUCTURE

- Training and awareness creation
- Brand promotion, merchandizing items
- Social marketing studies
- Credit and input support for farmers
- Compliance monitoring/certification

REVENUE STREAMS

- Product sale on national market, option for export
- Long-term revenues via:
- Sustainable sourcing
- Image support (clean, safe, responsible, green)
- International competitiveness

SOCIAL & ENVIRONMENTAL COSTS

- Residual health risks remain but unless high adoption rates are achieved (see Drechsel and Seidu, 2011)

SOCIAL & ENVIRONMENTAL BENEFITS

- Public health protection/savings along the food chain of USD 4.9 per dollar invested (Keraita et al., 2015)
- Urban supply with fresh produce

Support of wastewater treatment

Companies, e.g. Nestle, are using wherever possible municipal wastewater treatment facilities, but where these are non-existent or not efficient enough, the company invests in own facilities, returning treated water to the environment according to local legislation or their internal standards, *whichever is more stringent*.[2] The corporate responsibly model has thus the potential that it can catalyze treatment development also where public sector capacities or existing legislations are still in development. Moreover, many companies invest in the reuse of their own wastewater as part of their corporate social responsibility program. Box 13 shows the strong motivation of the textile sector in Pakistan to comply with international safety standards, independently of national demands and regulations.

A similar benchmarking peer-pressure can also be applied to public utility providers or their operational partners including those responsible for wastewater treatment (Danilenko et al., 2014) and their international suppliers, which gives the WHO supported *Sanitation Safety Plan* entry points for its institutionalization if it can become an internationally accepted tool for compliance monitoring.

Box 13. Corporate responsibility as driver for change

There is a common and natural overlap between "corporate responsibility" and "business interests" and while for some companies CSR might be more a marketing factor, it becomes essential for company growth or even survival for others, especially in the highly competitive supply sector. In Pakistan, for example, the textile industry tries to double its USD 13 billion export volume through different initiatives of which a key one is to provide *environment friendly clothing* to the world, in particular the European market. This target requires that Pakistan's cotton factories are fully compliant with international standards, including sound chemical management and wastewater treatment. Until now, many textile manufacturers use substandard or banned chemicals and dyes. However, international conventions signed by Pakistan strictly restrict the use of unapproved raw materials, including their disposal to environment without proper treatment. As European buyers increasingly demand compliance, such as the Sweden Textile Water Initiative[3] or the Partnership for Sustainable Textiles[4] which has brought together almost half of the German textile industry with policy-makers and civil society, this provides a strong incentive for the textile industry in Pakistan, Bangladesh, India, etc. to invest in responsible sourcing and water quality. To this effect, entrepreneurs associated with different sections of the textile chain offered for example financial assistance to the Pakistani government for establishment of combined industrial **wastewater treatment plants**. To reduce the use of harmful raw materials, training in resource use efficiency and alternative materials is being provided. Eventually, both, the compliance with safety standards and a more efficient resource use will be crucial components for company acceptance on international markets, or to meet the benchmarking targets for corporate environmental compliance performance. A first result of increased compliance among 44,000 licensed cotton farmers in Pakistan in 2011–2012 was a significantly reduced environmental footprint, like a 20% lower water use in irrigation, 38% less pesticide use and 33% less commercial fertilizer use while farmers' profitability increased by 35% (Shaikh, 2013). Such as strong incentive as provided in this case by the European customer is needed as in general companies remain cautious, especially in view of in-house water reuse which is a common part of corporates' 'good water stewardship' but has often trade-offs between water and energy savings (Newborne and Dalton, 2016).

Support of farm-based interventions

Supermarket chains are subscribing increasingly to international codes of conduct, like the Global Social Compliance Programme (GSCP) supported by the Foreign Trade Association (FTA) and its Business Environmental Performance Initiative (BEPI), the latter serving retailers, importers and brands committed to improving environmental performance in supplying factories and farms worldwide. Supermarkets or wholesale companies engaging out-grower schemes can opt for compliances with a 'responsible sourcing policy' or other best practices or codes of conduct to meet international quality and sustainability standards, and to remain internationally competitive. For instance, in Botswana and South Africa industries, bulk buyers and supermarket chains (Figure 264) are directly sourcing their crops from urban and peri-urban vegetable, grapevine or olive farmers to secure a continuous year-round supply, guaranteed by the use of (partially) treated wastewater for irrigation (Hanjra et al., 2017).

For risk reduction, farmers use drip irrigation and the companies put post-harvest measures in place to clean the crops from possible pathogenic contamination. This is in line with WHO's emphasis on health-based targets, where the irrigation water quality is less critical as long as measures to minimize exposure of crops and consumers are put in place (WHO, 2006). Thinking beyond the farm is also important, as even where irrigation water is safe, post-harvest contamination can be severe. Food safety interventions in markets, street restaurants and households are therefore of equal, if not higher importance, to safeguard consumers. This is even truer from an impact perspective, as the relationship between the supermarket and its farmers might only benefit the (middle and upper class) consumers of the supermarket and not the general public buying crops via traditional market chains.

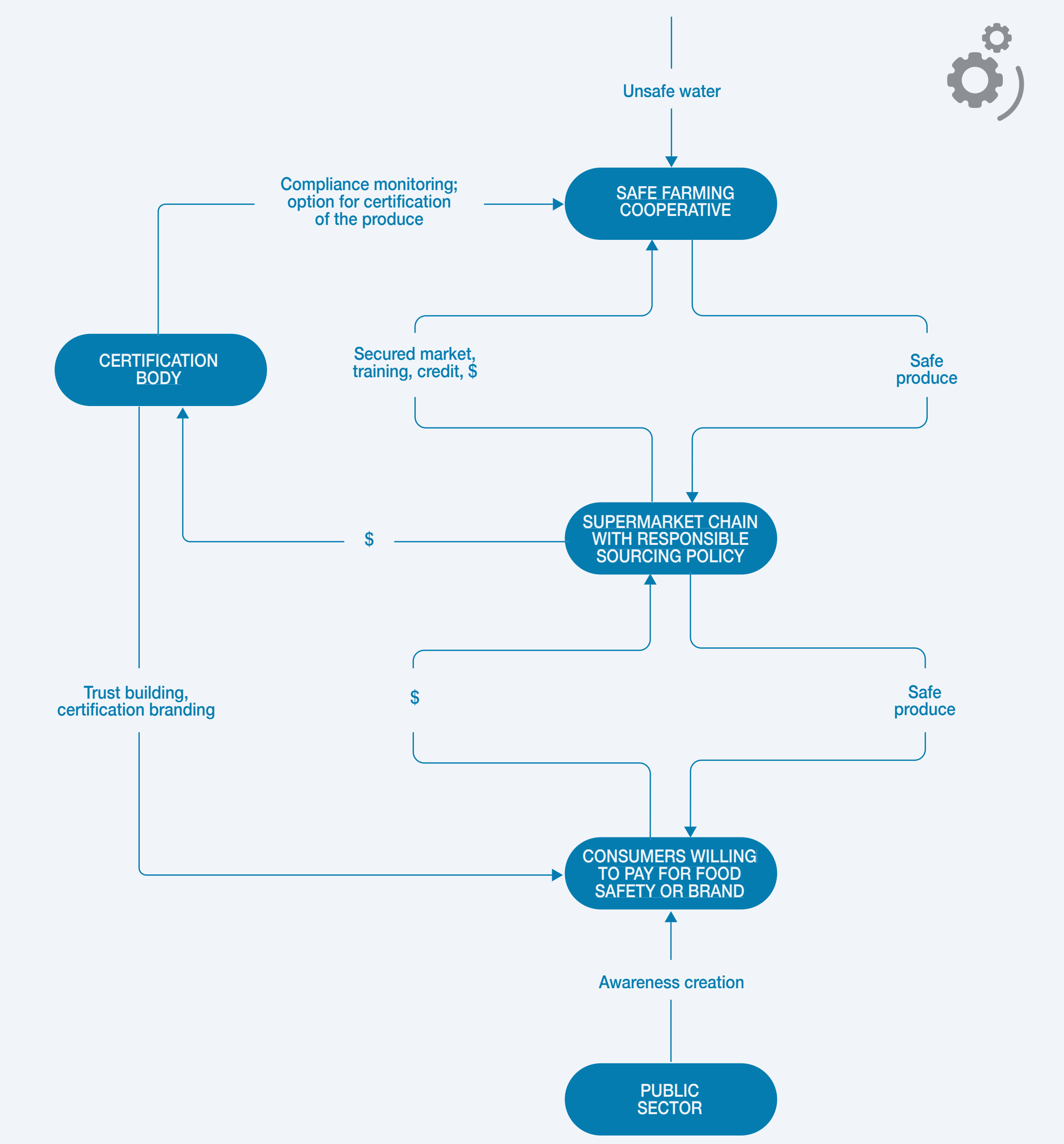
Support of post-harvest interventions

Social responsibility programs can be very powerful change agents in the post-harvest sector. In Ghana, for example, about 90% of the wastewater irrigated vegetables are sold raw as supplement to popular fast food dishes in the urban street food sector. For authorities and NGOs it is a challenge to enter or control this informal sector. However, the situation can be different for the private sector. Nestle, for example, supplies the street restaurant sector across West Africa with ingredients, like Maggi™ bouillon cubes, and uses its branding power to (i) maintain close links within the sector; and (ii) use it to advertise its brand. As part of Nestle's consumer service program, the company initiated in Ghana the formation of trader associations, the Maggi™ Fast Food (Seller) Association (MAFFAG) which is today the strongest association in Ghana's street food sector. MAFFAG regularly provides training in food preparation, cooking, environmental hygiene and food safety throughout the country, which combining elements of corporate responsibility with branding, free merchandise and product promotion. Compared with governmental workshops, the MAFFAG events attract large crowds, and their training programs are very well positioned for addressing food-safety concerns across the sector (Figure 265).

As the Maggi™ colors are today prominent in West Africa's street food sector, the high degree of brand recognition also implies responsibility to maintain the company's quality image. This motivation facilitated in Ghana the strong interest of MAFFAG in training in safe vegetable washing to minimize any food-related risk including those from vegetable irrigation (Amoah et al., 2009).

Based on the degree of educational efforts and risk awareness creation through public and private sector activities, the hope is that market demand for safe produce will slowly increase and catalyze further demand driven change. Wholesaler, trader or supermarkets can support this process through contracts with farmer cooperatives which allow them to secure a reliable crop supply while offering

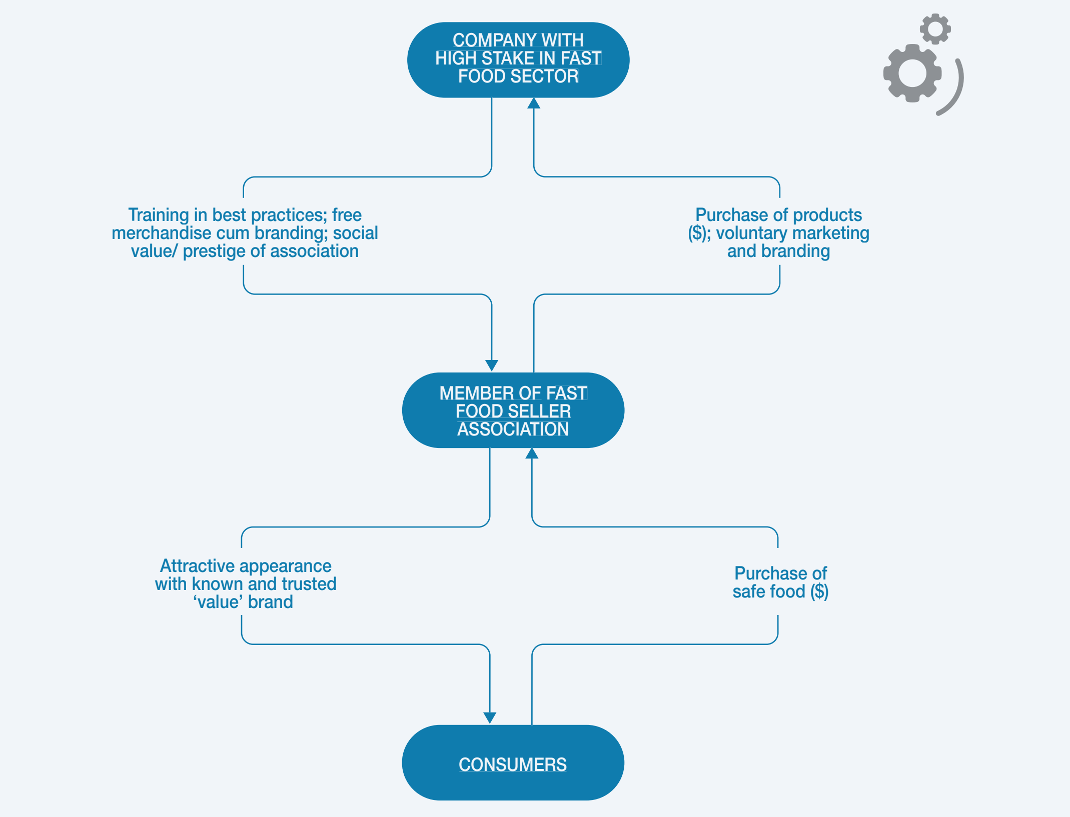
FIGURE 264. RESPONSIBLE SOURCING MODEL COMBINED WITH THE TARGET OF INCREASING MARKET DEMAND FOR FOOD SAFETY



inputs, training or credit. To qualify for such contracts best practices like safety measures could be made mandatory.

'Safe produce' branding could be an additional incentive mechanism for farmers and traders and support premium pricing. This could offer opportunities for third parties with capacities to perform compliance and quality monitoring to issue **quality certificates** as it is well established in the 'organic food' sector (Keraita and Drechsel, 2015).

FIGURE 265. SOCIAL RESPONSIBILITY CUM MARKETING STRATEGY MODEL FOR INCREASING FOOD SAFETY IN THE FAST FOOD SECTOR



Private sector support is not only important where the public sector struggles but also where initially only a minority of consumers with better education will support a safe food niche market. Although it can be anticipated that consumer demand will continuously increase through awareness creation, market based incentives might not be sufficient for success at scale and have to be complemented with other triggers for the adoption of safety practices to achieve compliance, e.g. with WHO Sanitation Safety Plans (Box 14).

Box 14. Triggering behavior change

Where health risk awareness is low and stakeholders along the food chain do not see a reason for engaging in safety practices, they might however change their behavior for other values or benefits which can contractually be agreed on. Examples are:

Tenure security: Many users of wastewater farm along streams on public land with limited tenure security if any, and constant fear of eviction. Land release, zoning and tenure security are thus

powerful incentives when demanding the implementation, e.g. of best practices, especially those which require farm-based infrastructure (Keraita et al., 2014).

Credit on condition: As similar incentive is the provision of low-interest credit to farmers who are applying safe irrigation methods.

In both cases, it remains the duty of the authorities to monitor farmers' compliance with their contractual obligations.

Fear of exposure: Where safety regulations cannot be monitored by authorities, media exposure (naming and shaming) can be a powerful alternative to steer compliance. Urban farmers and food restaurants in Ghana feared media exposure as it can trigger ad hoc policy response like eviction from the land or business closure.

Social values: Households might embark on safety measures if the right triggers and drivers can be identified and promoted through social marketing as it was successfully demonstrated in handwash and end-open-defecation campaigns. This might not be 'health' per se, but feeling of 'comfort', 'status', 'disgust', etc. Like in handwash campaigns, women in charge of food preparation should be a key target group.

Social marketing offers particular opportunities as it is only a relatively small step from the promotion of hand washing to salad washing (Drechsel and Karg, 2013). Also here private sector participation can be powerful as for example the Public-Private Partnership to Promote Handwashing between UNICEF and UNILEVER in West Africa has shown (see www.unicef.org/wcaro/overview_2765.html).

Potential risks and mitigation

In designing any business model, it is assumed that generic business risks are known and will be taken care of. However, some risks might be more model specific and will be acknowledged in the following:

Market risks: Household demand for the safer food is theoretically high, but does so far not translate in a different purchasing behavior (Keraita and Drechsel, 2015) although it can be influenced as the handwash campaign example (Box 14) shows. A larger risk is that the CSR company might not engage in the support of the farming communities using wastewater as long as they can source safer supply chains. Such (freshwater using) alternatives are however increasingly seldom in urban proximity.

Competition risks: Unsafe produce can have a price advantage. Awareness creation and social marketing flagging the difference between safe and unsafe produce can decrease the market demand/share of unsafe produce. Care has to be taken that safe and potentially still unsafe marketing channels are kept separate.

Technological risk: The involved technology for farmers, traders or restaurants is basic and in general affordable (Amoah et al., 2011).

Social equity related risks: Supporting women is a core element of many CSR programs. Social marketing campaigns, training, the formation of 'brand' association, etc. have a high potential to support women and gender inclusiveness. As urban vegetable farming on open spaces offers employment

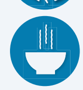
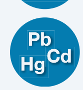
opportunities for rural migrants, any support through the private sector would be an important step towards social integration and poverty alleviation.

Political and regulatory risks: Corporate responsibility models by definition comply with local regulations. As the public sector is partner in the model, compliance will be monitored depending on local capacity. However, a challenge can come from a regulatory framework which is not supporting, as suggested by WHO (2006), a step-wise and multi-barrier HACCP approach to move towards safer wastewater irrigation or food safety in general.

Safety, environmental and health risks: The model helps to reduce risks where treatment systems are lacking and farmers use directly or indirectly untreated, partially treated or diluted wastewater. It builds on safety measures as recommended by WHO (2006) for this situation. Although these best practices target first of all pathogenic risk, the model can also address chemical risks if the sources can be controlled by the participating private sector entities through source pre-treatment and a 'zero waste' policy. The model follows the WHO recommendation of a step-wise and stakeholder inclusive approach to risk mitigation which is an intermediate step until (a) more comprehensive wastewater collection and treatment systems are in place, and (b) stricter safety guidelines can be implemented and enforced.

As the model is based on incentivizing human behavior change and a high degree of compliance with risk mitigation measures, **risks will remain** and have to be addressed through conventional mitigation measures (Table 61) supported by further awareness creation, capacity development and incentive systems (Drechsel and Karg, 2013).

TABLE 61. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 22

RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR/ ODOR	INSECTS	WATER/ SOIL	FOOD	
Farmer						WHO Sanitation Safety Plans with multi-barrier approach recommended along food chain, complemented with risk mitigation measures by the corporate sector.
Community						
Consumer						
Mitigation measures					  	

Key: NOT APPLICABLE; LOW RISK; MEDIUM RISK; HIGH RISK

SWOT analysis and business performance

The model is suggested for the common situation in sub-Saharan Africa, Asia and parts of Latin America where informal wastewater use is potentially threatening public health while local authorities have limited capacity to enforce restriction or change the situation, e.g. wastewater treatment is not available. The model builds on the rapidly growing opportunity of corporate social and environmental

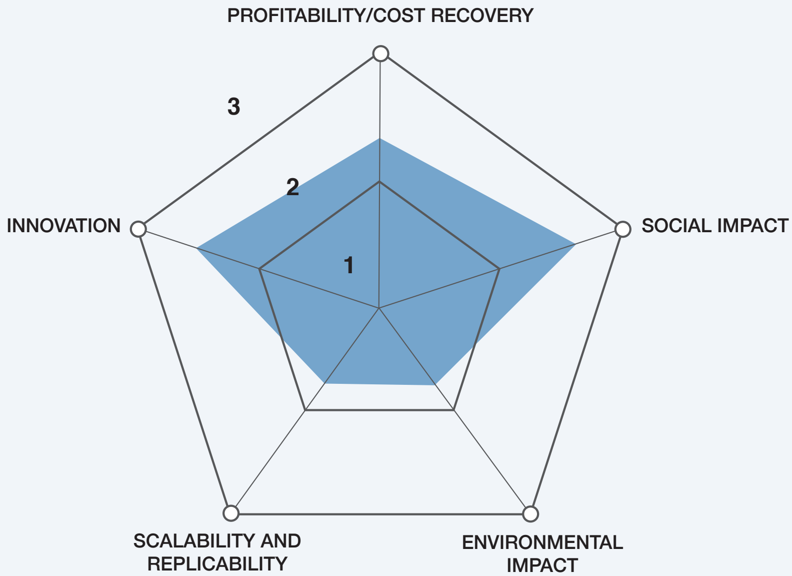
responsibility principles of the private sector (Figure 266) with related investments in the value chain. It argues for additional support to address key weaknesses of the model in particular in view of public awareness creation and the exploration of social marketing to catalyze behavior change and market demand. The model can support best practices on farm, but might have a wider outreach where it can target the post-harvest sector including consumers. The model offers possible incentives for making the crop value chain safer in the common situation where general risk awareness is still too low to rely on self-protection.

In comparison to other performance indicators the business model scores particularly high on social factors, via reduced expenditure on public health while supporting the informal irrigation sector which is often dominated by rural migrants or other social minorities looking for quick cash (Figure 267). Given the novelty of using CSR models to increase food safety, the model has certainly innovation potential. On the other hand, it requires more experience and practical examples before the scalability and replicability can be assessed. Given that social marketing requires context specific research, it is certainly not easily transferable. Also its environmental impact is limited as long as the focus is on human exposure and behavior change, and does not catalyze more wastewater treatment systems.

FIGURE 266. SWOT ANALYSIS OF THE CORPORATE RESPONSIBILITY MODEL TO IMPROVE FOOD SAFETY IN THE INFORMAL IRRIGATION SECTOR AND ITS VALUE CHAIN

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ CSR targets can catalyze change also where public sector policies and regulations are only emerging ▪ Irrigated farming in city vicinity is usually for the market, and not subsistence, thus private sector interest is likely ▪ Risk reducing options have been researched and translated into training materials, videos, etc. ▪ High social impact potential	**WEAKNESSES** ▪ Risk reduction depends on degree of best practice adoption; missing adoption targets can result in backlash ▪ Awareness creation among consumer and thus overall demand will take time ▪ Local trading companies without international visibility might feel no need for CSR ▪ Capacities in social marketing research only emerging ▪ Safe produce might not reach the poor
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Social and environmental responsibility commitments sharply increasing ▪ Existing PPPs (like global handwash campaign) could be expanded or at least provide lessons ▪ Piggy-backing on existing trader or farmer association with high market penetration	**THREATS** ▪ Unsafe produce can have a price advantage until awareness creation and social marketing leverage this in a positive sense ▪ Company might source alternative farming communities using clean water sources ▪ Some authorities may see private sector engagement as an intrusion into their domain

FIGURE 267. BUSINESS PERFORMANCE OF THE CORPORATE RESPONSIBILITY MODEL



Contributors

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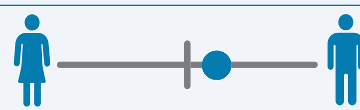
BUSINESS MODEL 23

Wastewater as a commodity driving change

Munir A. Hanjra, Krishna C. Rao, George K. Danso, Priyanie Amerasinghe and Pay Drechsel

In memory of Jeroen Ensink

Model name	Wastewater as a commodity driving change
Waste stream	Domestic wastewater
Value offer	Untreated, partially treated and treated wastewater for auctioning to farmers
Geography	Arid and semi-arid regions
Scale of business	Medium (function of irrigation demand and wastewater supply)
Location of supporting cases in the book	This model is in its presentation a hybrid of case & model and builds on observation in particular in Faisalabad, Pakistan and Gujarat, India
Objective of entity	Cost recovery [X]; Safety [X]
Investment cost range	Varies largely with type and size of treatment plant (USD 2–4 m for 100,000 inhabitants)
Organization type	Public (utility) and private (farmers)
Major partners in the case example	Water and Sanitation Agency (WASA), Chakera Farmers
Socio-economic impact	The auctioning process is socially inclusive. Wastewater main source of income and food security; health risks can be controlled and are accepted as offset by revenues

Gender equity	In many countries, auctioning will favour men as women have less access to land and capital	

Executive summary

This business model has been informed by two cases where wastewater auctioning is common, in Pakistan and India. With sufficient information being only available from the situation in Pakistan, the presentation of its model here follows a **hybrid of the business model and case templates** focussing on mostly Faisalabad/Pakistan.

With insufficient supply of freshwater of low salinity to support irrigated crop production, farmers in the dry climate of Faisalabad in Pakistan overcame organizational, infrastructure and legal obstacles to secure access to urban wastewater. Like for freshwater (canal water), also wastewater became a marketable commodity farmers pay for[1]. The wastewater provider, the Water and Sanitation Agency (WASA) in Faisalabad, uses public auctions for bulk sale of its wastewater to farmers, a system which

keeps WASA's transaction costs low, and is also reported from Gujarat, India. The farmers organize themselves into groups and the highest bidder gets the annual rights to reuse the wastewater and resell surplus water to other farmers. As the annual auction attracts several interested bidders, a floor price guarantee is not required and wastewater auction price is determined through a near competitive market. Despite the common experience that wastewater can only be sold cheaper than freshwater, it is not uncommon that farmers pay for the wastewater on top of their fees for canal water and up to 50% more for untreated wastewater than treated wastewater, given the lower nitrogen and higher salinity levels of the latter. The auction process allows WASA to cover its pumping costs and to maintain administrative control over the wastewater. Most of all, the process turns informal wastewater use into formal wastewater use and gives farmers and authorities a platform for dialog. This is missing in many countries where informal wastewater use is a grey sector. The dialog offers opportunities for negotiating health risk mitigation via alternative treatment options, which match farmers' needs while enhancing safety (WHO, 2006). The high market value of wastewater offers opportunities to introduce incentives (like extra water allocations) in support of the compliance with safety measures.

KEY PERFORMANCE INDICATORS OF THE PAKISTAN CASE (2012–2014)

Land use:	Around Chakera: About 456 ha (71% of farm area) under untreated wastewater irrigation, ca. 25–35 ha under treated wastewater, 12–15 ha with freshwater supply, ca. 85–90 ha with partially treated or mixed sources, and 44 ha without irrigation					
Water treated:	Ca. 37,000m^3 per day (the design capacity is about 90,000m^3 per day. About 79,000m^3 of wastewater enter the plant premises, of which about 53% are redirected for irrigation before reaching the first treatment ponds					
Capital investment:	N.A.					
Labor employment:	N.A.					
O&M costs:	About USD 350,000 sewage system O&M costs (Faisalabad West) in 2012–2014, of which the O&M budget of the treatment plant is about USD 30,000 (WASA, 2014)					
Annual revenue:	Sewerage charges as part of water bill, property tax and non-tariff income from leasing of land to farmers and wastewater auctioning of around USD 6,000–7,000					
Output:	Secondary treated wastewater					
Potential social and/or enviornmental impact:	Job creation/income along the sanitation value chain (i.e., farmers, market sellers, and input suppliers); possible health risks for farmers and urban consumers					
Financial viability indicators:	Payback period:	Data not available (N.A.)	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

This business case pertains to wastewater reuse as seen on the example of Chakera, located on the western outskirts of Faisalabad City in Pakistan. Faisalabad, the third largest metropolis in Pakistan, has an estimated population of 3.6 million (WASA, 2014). Like in other larger cities in Pakistan, the semi-autonomous Water and Sanitation Agency (WASA) is responsibility for water supply and sanitation. It provides about 65–75% of the city area with a sewerage network which is linked to larger channels for final disposal of the wastewater in the Chenab and Ravi rivers. Faisalabad's wastewater treatment plant at Chakera can treat about 25–30% of the collected wastewater. The system consists of a series of waste stabilization ponds (WSP). Given the city's largely flat topography, 31–40% of WASA's O&M costs per year are for electricity (pumping).

Under the arid climate with annually about 350 mm rainfall, irrigation is most common and traditionally supported by canals fed by River Chenab. Due to increasing demands, water supply is declining since

a few decades and inadequate for many regions and/or year round production. Common crops are wheat, sugarcane, cotton, vegetables, fruits and fodder crops (clover, Lucerne, barley, etc.). Chakera is a typical suburban village where irrigation canals stopped providing the needed water years ago (ca. 2002). As groundwater is saline, the only remaining option is wastewater, which is abundant in Chakera given its proximity to the city of Faisalabad. However, initially WASA did not support farmers' request for waste and it took some court cases before WASA agreed. The current system is that WASA auctions the wastewater, and this can be untreated, partially treated or treated wastewater. WASA also rents out land with wastewater access (Weckenbrock et al., 2011).

It is noteworthy that more than 90% of the farm households choose untreated wastewater although treated wastewater is in same proximity and cheaper. Freshwater alternatives like canal water and groundwater are too scarce and can only serve less than 5% of the water market. The reasons for choosing untreated wastewater are of agronomic nature, directly affecting farmers' livelihoods: the treatment process is increasing water salinity (see below) beyond what some of their crops can tolerate while significantly reducing the nitrogen and phosphorus content of the water. In fact, 70% of farmers using untreated wastewater reported that they stopped applying fertilizers, and 24% only used very targeted fertilizer applications (Ensink, 2006; Clemett and Ensink, 2006).

Market environment

Demand for irrigation water in Punjab province of Pakistan has increased steadily over the past decades, far beyond what can be supplied. Chakera is one of the villages with irrigation canals but hardly any water. However, farmers in the eastern boundary of the village began to use wastewater coming from Faisalabad. With visible gains in production and income, this informal practice spread among farmers in other parts of the village and beyond. With the increase in demand for wastewater, farmers constructed new irrigation canals to make wastewater available in more parts of the village and the existing canal-water infrastructure was modified to facilitate wastewater irrigation. Over the years, wastewater has become the most important source of water for irrigation with benefits clearly exceeding risks, while the majority of farmers having in fact no alternative (Clemett and Ensink, 2006; Weckenbrock, 2011). There are about 2,200 ha irrigated with wastewater around Faisalabad, and 32,500 across Pakistan (Weckenbrock et al., 2011).

Wastewater farmers around the WSP have, since the construction of the treatment plant, organized themselves and gone to court to establish their rights to use wastewater. For the water use, they pay WASA which allows WASA to maintain control over the resource as a service provider. The water fee ranges from USD 10 to USD 62 per hectare per year depending on the quantity and the quality of wastewater. The payment is on top of what farmers pay for freshwater[2]. The highest fees were paid for untreated wastewater with lower fees paid for wastewater from anaerobic ponds (Clemett and Ensink, 2006). A unique feature of this business case is that the wastewater is sold annually in bulk by WASA through an open auction to the highest bidder from the village, and the winning farmer resells the surplus wastewater to fellow farmers (Box 15). Through the bulk auction of wastewater, WASA outsources likely transaction costs of dealing with individual farmers such as water allocation, monitoring, compliance and collecting the wastewater fees, which is reducing the service provision largely to the energy costs for water pumping, the cost item WASA tries to recover from the business.

Macro-economic environment

The agriculture sector continues to play a central role in Pakistan's economy. It is the second largest sector, accounting for over 21% of gross domestic product (GDP), and remains by far the largest employer, absorbing 45% of the country's total labor force. Given the low precipitation, major investments in water resources management are required to prepare Pakistan for its growing population

Box 15. Wastewater auctioning process

The auction process for treated/untreated wastewater starts with the announcement of the bidding date to farmers. The farmers organize themselves into small bidding consortiums/ groups and each group nominates a bid leader, after background negotiations on the maximum bid amount and the exit strategy should the bid amount go higher than their expectations and upper ceiling. On the bidding day, farmers congregate at the venue and group leaders contest the bid in the open auction. Opening bid price is generally the last year's auction price, and then the bid amounts are raised gradually upwards through calling the amounts publically. Only one bid is left with the auctioneer at a time, and a punt by another group leader raises the bid with the hope to snap up the wastewater. Group rivalry and market competition are all at play along with some pride and political capital in winning the bid and this often leads to intense 'bidding wars' across the group leaders. Bids are conveyed to the auctioneer through various gestures, including waving of hand or cloth. The highest bidder wins the auction and WASA auctioneer announces the name of the winning bidder and the completion of the wastewater sale. The winning bidder/ purchaser of the wastewater is generally a wealthier farmer within the village – not an investor or company, and not a speculator. Further, the bid amounts are never undisclosed such that water prices/charges become known to all farmers spot on. Strong cooperation and greater understanding on water allocation rules among farmers ensures that all farmers get water and no one is excluded from using the wastewater, at payment to the winning bidder, like USD 6 per year for a one-hour allocation every ten days. These can be paid in different instalments, which benefits less wealthy farmers unable to pay the fee in a single instalment. There are no reported cases of abuse of power (Weckenbrock et al., 2011; Clemett and Ensink, 2006).

and risks through floods and droughts. One part of this is the promotion of water recovery and reuse. Water quality monitoring in the irrigation sector is generally lax. A main challenge will be to develop local guidelines for cost effective risk mitigation measures, which consider actual exposure and help to optimize the gains to farmers from reuse while reducing risks to actors along the wastewater value chain.

Business model

As a service provider, the enterprise (WASA) charges for the wastewater it is collecting, managing and treating as far as its facilities allow. The wastewater is not given away for free and WASA remains in control of its allocation. Although the revenue stream from agriculture is a minor one given WASA's overall budget, the WSP has limited maintenance costs, and the revenue allows to cover a good part of WASA's pumping costs in the Chakera area.

The auction model has direct and indirect advantages: WASA transfers the water rights (and related pro-poor obligations) as well as the transaction costs of reaching out to individual farmers to the winning bidder who is in charge of supporting all farmers who agree to a transparent pro rata price. There is no penalty to any farmer for breaking the informal contract with the winning bidder, due to high water demand, and collections from the farmers far exceed the bid amount. This allows the business to remain viable at bidder's end, and even provides for the maintenance of the water courses and seasonal canal cleaning. Also, a maintenance charge is factored into the price of wastewater farmers pay. The winning bidder pays WASA on a quarterly basis and collects water charges from the individual farmers in convenient rates. Further, WASA uses a price discrimination model to encourage the reuse

of treated wastewater, i.e. the untreated wastewater is auctioned at highest prices followed by partially treated and treated at the lowest price. WASA also earns revenue from leasing of its land (wastewater access priced in). The business has a long history of cooperation and **turns informal wastewater use into formal wastewater use**, which opens space for dialog to address, e.g. farmers' problems with the current wastewater treatment system. A summary of the key elements of the Business model canvas is outlined in Figure 268 below.

FIGURE 268. BUSINESS MODEL CANVAS – WASA PROVIDES TREATED, PARTIALLY TREATED AND UNTREATED WASTEWATER FOR IRRIGATION

KEY PARTNERS

- City of Faisalabad
- Provincial government (PAK-EPA, Department of Health)

KEY ACTIVITIES

- Conveyance of untreated, treated and partially treated wastewater
- Auctioning and sales of wastewater (bulk for resale)
- Setting the price of wastewater through auction mechanism
- Land lease

KEY RESOURCES

- Wastewater treatment facility and related canal system
- Service attitude

VALUE PROPOSITIONS

- Provision of a reliable supply of irrigation water of different quality, either directly or via land lease
- Creation of a formal business platform to discuss wastewater treatment and alternative risk mitigation options

CUSTOMER RELATIONSHIPS

- Contracts with winning bidders
- Direct lease agreement

CHANNELS

- Direct contact
- Public auctions
- Canal system to deliver wastewater

CUSTOMER SEGMENTS

- Farmers and farmer associations around Chakera

COST STRUCTURE

- Capital investment
- O&M for wastewater collection, treatment, delivery
- Service provision and fee collection

REVENUE STREAMS

- Water and sewerage charges to households
- Governmental support
- Wastewater sale and land rental (miscellaneous revenue stream)

SOCIAL & ENVIRONMENTAL COSTS

- Occupational health risks for farmers and food safety risks for consumers, especially if food is eaten uncooked
- Potential environmental impacts including nitrate pollution and loss of soil productivity

SOCIAL & ENVIRONMENTAL BENEFITS

- Farmers job security and creation
- Contribution to food security
- Freshwater saving
- WASA maintains its mandate as wastewater service provider

Value chain and position

WASA is responsible for water supply and sanitation services in the city and has a natural monopoly on supplying any wastewater to the farmers. With the increasing water scarcity and the need to produce more vegetables to supplement local production of food crops, WASA has come under increasing pressure to provide wastewater for irrigation across locations. This can be treated, partially treated and untreated wastewater. However, only farmers with access to untreated wastewater were able to save on fertilizers and achieve higher cropping intensities as well as year-round cultivation which allowed them to earn on average USD 600 per hectare per year more than farmers who used regular irrigation water, easily absorbing the higher water fees set by the WASA (Clemett and Ensink, 2006). By charging farmers for the use of wastewater, WASA is able to recover some of its O&M costs for the wastewater treatment plant, while its main revenue stream (ca. 60%) are water supply and sewerage charges (2:1) billed to the residential, commercial and industrial sectors (Figure 269).

Institutional environment

In Pakistan's Punjab province, water services in the largest cities are provided by publicly-owned Water and Sanitation Agencies (WASAs). WASAs are accountable to both local- and provincial-level authorities, i.e. the respective City Development Authorities, and the Housing Urban Development and Public Health Engineering Department of the Government of Punjab.

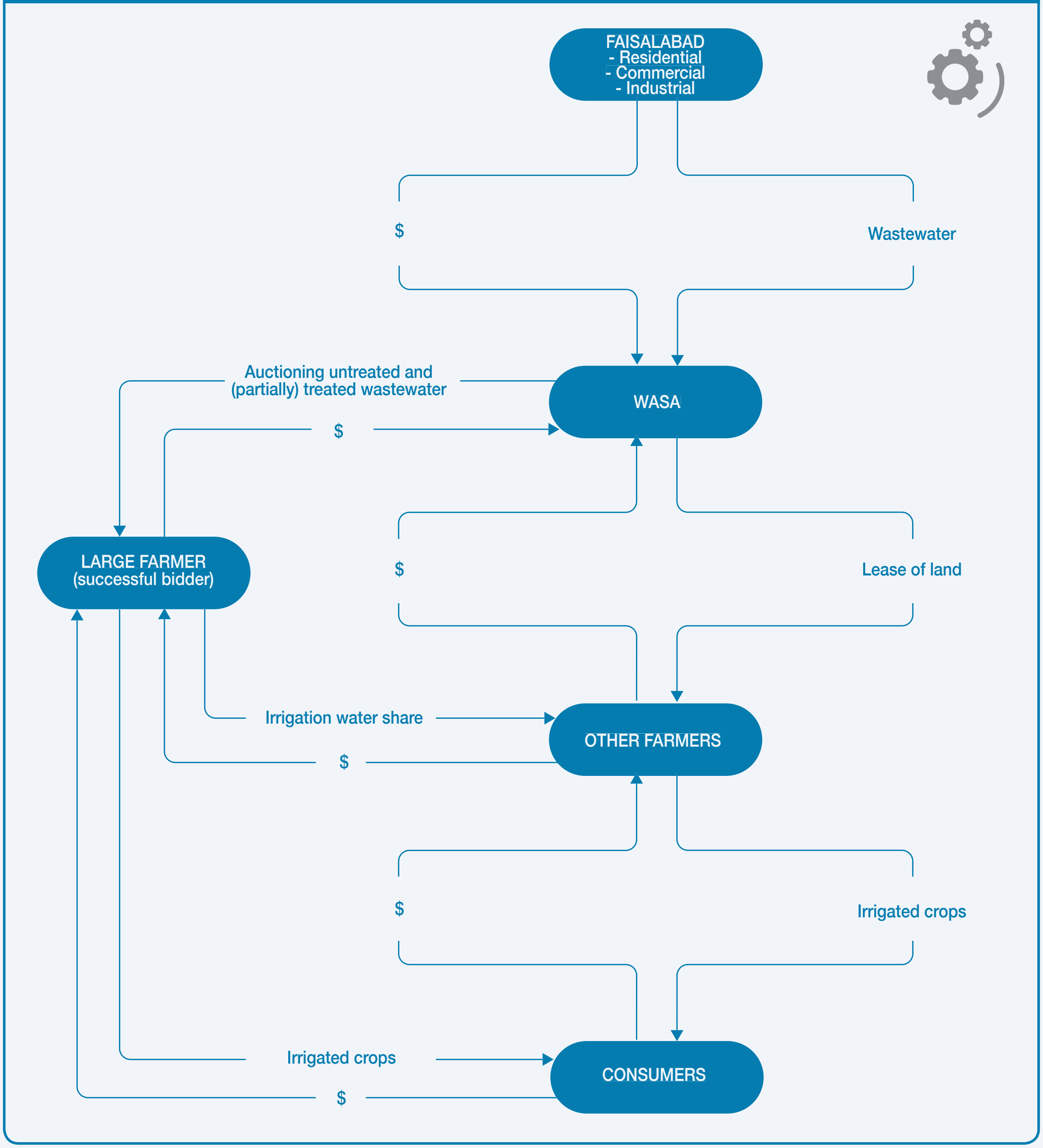
The WASA in Faisalabad was created in 1978. In the 1980s WASA bought land at the outskirt of the city (Chakera village) for the purpose of building a WSP and its operation started in the late 1990s. During this period, there was a lengthy court case between the farmers and WASA over the right to use wastewater. The first court case accepted the lack of alternative water sources, and gave farmers the right to use wastewater for irrigation and to generate income to support their families. The court provided this ruling because there was no alternative canal water for the farmers to use for irrigation. The WASA appealed this decision and the court granted them the water rights, banning wastewater irrigation. As this decision was hard to implement, both parties had to reach an agreement whereby farmers agreed to pay WASA for the use of wastewater. This provides farmers with some legal standing of the practice and institutional support for wastewater reuse while WASA remains in charge as service provider (Clemett and Ensink, 2006). That wastewater can be sold for agricultural purposes is supported by the National Sanitation Policy (Ministry of Environment, 2006). However, there is no universal public acceptance of wastewater use and it is not supported, e.g. by the Ministry of Health.

Technology and processes

The wastewater treatment plant in Faisalabad was built in 1998 and designed for an inflow of nearly 90,000m^3 per day of (mostly) domestic wastewater at a site where untreated wastewater had been used for the past 50 years for the cultivation of vegetables, fodder, wheat and sugarcane. The plant is a basic waste stabilization pond system (WSP), consisting of six anaerobic, two facultative and four maturation ponds (Figure 270). Its operational costs are low while performance in terms of the removal of pathogens, BOD and TSS, as well as ammonia and phosphorus is good. It was expected that WASA sells the reclaimed quality water to farmers to recover some of its O&M costs. In practice however, the majority of farmers continued using the untreated wastewater, which they take from wastewater channels not passing the plant but also the main channel just before it reaches the first WSP ponds (Clemett and Ensink, 2006). Thus, from the expected average daily inflow into the treatment plant of 79,300m^3 per day, about half is diverted before it enters the plant. As a result of the lower flow, retention periods increased and so evaporation and water salinity, which stopped farmers being willing to pay for treated wastewater.

A much smaller quantity of water is also diverted from the anaerobic and facultative ponds. Because of the limited demand for final effluent by farmers[3], much of the treated wastewater has to be disposed

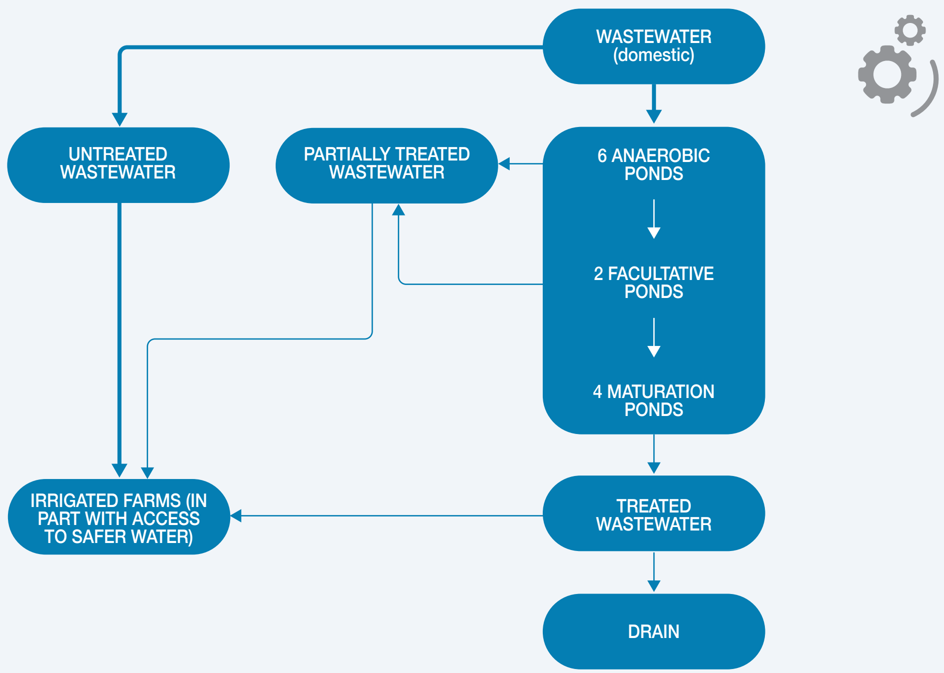
FIGURE 269. WASA BUSINESS PROCESS FLOW



of into the next drain. Other farmers access wastewater which is not flowing to the treatment plant. In total about 60,000m^3 of wastewater is used per day by about 200–300 farmers in Chakera.

Given farmers' dissatisfaction with the treated wastewater generated by pond-based treatment systems, alternative treatment options as well as other risk mitigation measures could be introduced to farmers (WHO, 2006), and linked to the sale of wastewater (or as incentive to a free water allocation).

FIGURE 270. WASTEWATER REUSE FOR IRRIGATION IN CHAKERA, FAISALABAD, PAKISTAN



Funding and financial outlook

In general, the Water and Sanitation Agencies across Pakistan struggle to collect sufficient operating revenue to pay for their operating costs. Also the contribution of wastewater auctioning (Table 62) is financially negligible but allows WASA to maintain control over the wastewater use and achieve some O&M cost recovery with limited transaction costs. The annual income from leasing of land and auction of wastewater were in 2012–2013 about USD 45,000 which is more than the O&M budget of the pond-based sewage treatment system in Faisalabad and about 15% of the total O&M costs of the related sewer system in Faisalabad West. Compared to the revenues from sewerage charges which were in 2012–2013 about USD 2m, the amount is however very modest (WASA, 2014).

Because of the application of nutrient-rich wastewater, wastewater farmers in Chakera save on fertilizer; and although more pesticides are needed, the net gains are so substantial, that WASA could increase its water fees.

Socio-economic, health and environmental impact

The auctioning process as described in Box 15 has been considered as socially fair as it helps also small holders to access a share of the available water. As long as the water is not sufficiently treated, health risks remain. This is in part an accepted professional risk, as the benefit-cost ratio was significantly higher for wastewater than freshwater farmers, as well as farmers using untreated compared to treated wastewater (IWMI, 2009; Baig et al., 2011; Clemett and Ensink, 2006). Similar situations were also reported from other cities (Van der Hoek et al., 2002; Hussain et al., 2002).

TABLE 62. SUMMARY OF IRRIGATION WATER SOURCES AND INSTRUMENTS USED TO ALLOCATE WATER

SOURCE OF WATER	INSTRUMENT USED	AREAS IRRIGATED (HA)	NUMBER OF FARMERS
Canal (paid to Irrigation Department)	Flat rate per acre (varies by season)	12–15	5
Treated wastewater	Priced via land (unit) lease	25–35	Ca. 20
Partially treated (incl. mixed wastewater / fresh water)	Auction (bulk)	85–90	40–50
Untreated	Auction (bulk)	457	150–175

Sources: Weckenbrock, 2011; IWMI, 2014, unpublished.

Overall production costs were highest for freshwater farmers, especially if ground water pumping was required, and lowest were where the wastewater replace fertilizer needs. In addition, farmers using wastewater were able to produce more crops per year, including vegetables which require daily watering and care, and created more jobs. Where vegetables are grown, they are usually cooked which is reducing possible health risk for consumers.

Negative externalities relate mostly to pathogens (especially hookworm infections) and too high nitrogen levels for certain crops, like root crops. Risk reduction measures against hookworm infections, like protective footgear or de-worming campaigns are so far insufficiently used to reduce risks for farmers.

Scalability and replicability considerations

With increasing population and food demands, it appears inevitable that demand for water and its reuse will expand in Pakistan. Given the slow growth of the wastewater treatment sector, untreated or partially treated wastewater will continue to be the leading source of water (Ensink et al., 2004ab). The lessons from the well-researched Faisalabad case offer authorities an opportunity for engagement with farmers to provide regulatory oversight and bring options for health risk reduction into the business discussion. Especially the auction model has a high potential for this given its low transaction costs. Thus, WASA could be flexible in view of financial cost recovery, while targeting farmers' buy-in in risk reduction options which will probably easily pay off for the city in terms of reduced public health expenditures. Replication of wastewater auctions have been seen in other villages across WASA's jurisdiction as well as in India (Box 16). The wastewater auction model could thus be scaled across the region in all those locations where authorities see the livelihood and food security opportunities that wastewater with/out treatment offers as long as farmers and authorities can jointly work on modalities like risk mitigation. Dialog between authorities and farmers can also address other issues: The increased water and nutrient availability calls for changes in cropping patterns and fertilizer rates where farmers might need assistance. On the other hand, many treatment plants are poorly sited when it comes to optimizing their water reuse potential.

Support by the private sector will be needed where industrial effluent is mixed with domestic wastewater, which is according to Weckenbrock et al. (2011) so far not a problem. While pathogenic risks from domestic wastewater can be addressed also on farm via so called 'non-treatment' options (Amoah et al., 2011; Mara et al., 2010), chemical contaminants from industrial origin require conventional treatment, ideally at source. The willingness of the Pakistani private sector to accept this responsibility is high given its wish to comply with European import requirements (see **Corporate Responsibility Model 22** in this publication).

Box 16. Direct and indirect wastewater auctioning

Also in **India's Gujarat**, many cities reportedly sell access to treated and untreated wastewater for use in agriculture, and also auctioning is common (Palrecha et al., 2012). The use of wastewater is recognized by the Government of Gujarat and water charges are being collected at the same rates as applicable for lifting water from notified rivers. Competition is high for its assured availability and nutrient value. Wastewater auctions are held annually, for example in the Kutch district. In the villages of Anadpur (Yaksh), Mota Dhavda and Sanyara, wastewater is auctioned annually at USD 100–200 for irrigating 2 to 6 ha in each village. With increasing demand for freshwater in cities, there have been trade-offs between farmers and the cities for availing freshwater in exchange for wastewater. There exists an MOU, which was signed between the farmers of a wastewater cooperative in Rajkot and the Rajkot Municipal Corporation since around 1970 according to which farmers are not allowed to lift water from Lalpari Lake for irrigation to allow supply to Rajkot city. In exchange, wastewater is supplied to the farmers by the Corporation, similar to the Iran case under Model 20 in the catalogue. This MOU is still operational.

Like in Pakistan, many farmers in Gujarat irrigate with wastewater despite having the option of groundwater irrigation because they see wastewater as (a) more reliable and accessible throughout the year; (b) cheaper to lift; and/or (c) more profitable because of its nutrient value leading to higher yields and savings in fertilizer input costs (Palrecha et al., 2012; www.peopleincentre.org/PiC/?p=748). Also the nutrient value of fecal sludge has been recognized, with reported sludge auctioning in Karnataka, India (see Business Model 17).

Auctioning replenished groundwater has been described from other countries as a new perspective for financing water reuse with the issuance of groundwater credits where treated municipal wastewater effluent is used to recharge groundwater. In Prescott Valley, in the state of Arizona in the **USA**, groundwater credits created in such a manner was auctioned in November 2007 with the help of WestWater Research. The winning bidder, Water Property Investors LLC (a New York-based water resource investment firm) agreed to pay USD 67 million in total annually (USD 20.16/m^3) for the right to withdraw 3.3 million m^3/yr from the ground. Prior to finalization of bids, Aqua Capital Management LP agreed to pay USD 53 million for the equivalent rights, which guaranteed the floor price of the auction (GWI, 2010).

Potential risks and mitigation

In designing any business model, it is assumed that generic business risks are known and will be taken care of. However, some risks might be more model specific and will be acknowledged in the following:

Market risks: Most farming locations where wastewater is formally or informally used are in close proximity to major urban markets and well positioned to respond quickly to market needs, save on transport costs and deliver high-value crops also in the lean season when revenues peak. As crops produced with wastewater or freshwater are mixed in markets and risk awareness along the food chain is commonly low, market related risks are limited.

Competition risks: Only with increasing risk awareness, the potential of competition from freshwater farmers could be growing. So far this awareness is in most low-income countries limited.

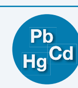
Technology and performance risks: WHO approved low cost wastewater treatment and non-treatment options are available which either treat the water before reuse, or on-farm accompanied by safe irrigation practices and post-harvest safety measures (Amoah et al., 2011). Care has to be taken that employed technologies like in the presented case study, do not have side effects (nutrient loss, salinity increase) which are not accepted by farmers.

Political and regulatory risks: The regulatory framework has to acknowledge wastewater as a commodity with value, which water authorities can market. This can give authorities bargaining power to lobby for safety practices.

Social equity related risks: The share of men and women in the informal irrigation sector differs between countries and cultures. In Pakistan, women have significant difficulties accessing irrigation water, and less responsibilities in irrigation than men. In other countries, it can be the opposite, with changing roles along the value chain. However, under the current auctioning conditions, no (additional) gender related discrimination has been reported, although the process is male dominated while there are value chain advantages for women.

Safety, environmental and health risks: The model applies the WHO (2006) recommendation of a step-wise and stakeholder inclusive approach to risk mitigation which is an intermediate step until (a) more comprehensive wastewater collection and treatment systems are in place, which farmers also can accept; and (b) stricter safety guidelines can be implemented and enforced. Within this trajectory, risks, risk monitoring and risk mitigation measures remain important (Table 63) even if the dialog between authority and farmers will lead to the adoption of farm-based risk reduction measures (safer irrigation practices, on farm water treatment, crop restrictions).

TABLE 63. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 23

RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR/ ODOR	INSECTS	WATER/ SOIL	FOOD	
Farmers						After introduction of farm based risk reduction measures, their adoption has to be monitored.
Community						
Consumer						
Mitigation measures						

Key: NOT APPLICABLE; LOW RISK; MEDIUM RISK; HIGH RISK

SWOT analysis and business performance

The strength of this business case is its ability to develop cooperative working relationship with farmers based on principles of mutual interest (Figure 271). By this approach, the authorities from the

WASA are able to negotiate land rent with farmers and implicitly determine the price of wastewater with the farmers leasing land from WASA. Another significant strength is the application of auction mechanism in setting the price of wastewater and thus following market principles in determining the price of wastewater.

While joint business between wastewater suppliers and users might be common where treated wastewater is offered to farmers, the case of WASA auctioning untreated wastewater should allow negotiating crop restrictions and other on-farm risk mitigation options. Another entry point for safety regulations is that farmers actively engaged in the discussion about water, organized themselves and did not shy away from legal battles. Also this offers opportunities to formalize the otherwise informal wastewater use.

The institutional linkages between both parties go far beyond other situations and countries where the use of untreated wastewater is considered illegal or authorities do not engage at all, or only with disciplinary action. WASA's engagement, however, and the acceptance of wastewater as a marketable commodity provides authorities with an instrument for the **introduction of a variety of possible risk mitigation options**, which are recommended by the WHO (2006) for the safe use of wastewater

FIGURE 271. SWOT ANALYSIS OF CHAKERA VILLAGE BUSINESS CASE DESCRIPTION

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Wastewater accepted as commodity ▪ Low O&M of the treatment plant ▪ Cooperative working relationship (dialog between partners) ▪ Service attitude ▪ Auction pricing mechanism ▪ Continuous supply of wastewater	**WEAKNESSES** ▪ Inter-authority dialog on a joint reuse strategy for minimizing risks while maximizing benefits missing ▪ Treatment process (e.g. retention time) needs to be adjusted to avoid unnecessary changes in salinity and nitrogen levels which do not serve reuse objectives (farmers prefer untreated wastewater over treated wastewater)
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ High agricultural wastewater demand and legal support of water reuse ▪ Wastewater sharing arrangements ▪ Freshwater savings ▪ Auctioning gives an instrument for dialog on risk reduction ▪ Urban population growth resulting in increasing food (and agricultural water) demand ▪ Occupational and consumer health risks from pathogens can be minimized even without treatment plants if WHO (2006) guidelines are followed	**THREATS** ▪ Farmers exposed, e.g. to hookworms ▪ Possible human health risk may decrease demand for crops ▪ Potential conflicts due to worsening water scarcity and higher agric. demand than domestic wastewater supply ▪ Changes in policy on reuse ▪ Untreated industrial effluents may increasingly comingled with domestic wastewater ▪ Urbanization and loss of farmland

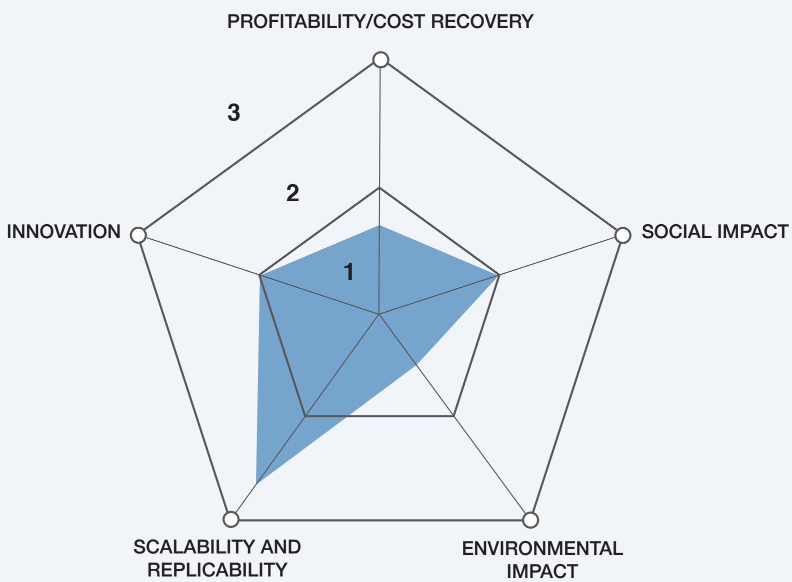
in agriculture. The market value of wastewater allows in addition the introduction of incentives (like extra water allocations) in exchange of compliance with safety measures.

WHO had realized with their 2006 guidelines that their 1989 water quality thresholds for wastewater irrigation as main risk barrier was in many countries unachievable due to the overwhelming challenge of wastewater collection and treatment. Therefore, WHO (2006) started emphasizing alternative risk barriers to protect farmers and consumers. So even where untreated wastewater is used, there are still multiple options for risk minimization, which include safe irrigation practices (Amoah et al., 2011; Mara et al., 2010).

A particular challenge in Faisalabad is that farmers prefer untreated wastewater compared to treated effluent. While untreated wastewater is considered high in nutrients and low in salinity, treated wastewater is considered low in nitrogen and – due to evaporation in the treatment ponds – high in salinity. In fact, the few recorded negative perceptions related to wastewater usually concern more plant growth than human health (Weckenbrock, 2011). A dialog between authorities and farmers should address these perceptions targeting a redesign of the local treatment plant's retention time. The hope is that participatory planning will lead to mutually acceptable standards for water quality and solutions for wastewater risk reduction which could become part of the business deal (Clemett and Ensink, 2006).

The innovative capacity of the model lies in the opportunity of a dialog on the trajectory from unsafe to safe wastewater use, with a relatively high scalability and replication potential due to its low costs. With neighbouring villages investing in pipes to access the wastewater, the models appear scalable as far as water is available, and replicable where policies support a dialog that helps negotiating risk mitigating measures (Figure 272). While the auctioning is not influencing water quality and the environment, it could help the stakeholder dialog which is central to any Sanitation Safety Plan (WHO 2015).

FIGURE 272. RANKING RESULTS FOR THE PRESENTED WASTEWATER AUCTIONING BUSINESS MODEL



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Case descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2014/15. As business operations are dynamic data are likely subject to change.

Notes

1 Groundwater is of poor quality in the area of Chakera. In general, accessing groundwater is costlier than wastewater, either because of expensive tube well installation, maintenance and pumping fuel prices, or because of paying tubewell owners (Weckenbrock, 2011).

2 When asked about the reason why farmers still pay for freshwater in spite of not having received any for decades, several farmers indicated that the amounts are low and they simply preferred not to instigate trouble (Weckenbrock, 2011).

3 Some farners can only access treated wastewater due to the local topography.

The case has been dedicated to Dr Jeroen Ensink (1974–2015) who worked with IWMI in Faisalabad on safe wastewater irrigation for many years.

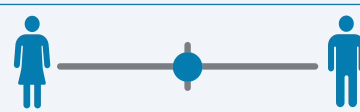
www.justgiving.com/fundraising/The-Jeroen-Ensink-Memorial-Fund

BUSINESS MODEL 24

Farmers' innovation capacity as driver of change

Sena Amewu, Solomie Gebrezgabher and Pay Drechsel

Model name	Farmers' innovation capacity as driver of change
Waste stream	Domestic grey water, wastewater-polluted stream water
Value offer	Partially treated wastewater for crop irrigation
Geography	Suburban low/wetlands used by farmers
Scale of business	Small scale (community)
Location of supporting cases	This model is in its presentation a hybrid of case and model and builds on observation in particular in Southern Ghana
Objective of entity	Social/Environmental enterprise [X]
Investment cost range	USD 15,000–25,000
Organization type	Community based organization
Major partners in the case example	Farmer association, Friends of Ramsar Site (NGO), Environmental Protection Agency, Wildlife Division of Forestry Commission, local assemblies, UNEP, Ministry of Food and Agriculture (MoFA)
Socio-economic impact	Fresh food for urban households. Every USD invested in on-farm treatment and post-harvest safety returns up to USD 4.9 in public health cost savings
Gender equity	**Generally balanced, but gender roles vary along value chain**



Executive summary

This business model has been informed by observations from wastewater using farming communities in India and West Africa where farmers show a significant innovative spirit to adapt either to declining water quality (Buechler and Mekala, 2005) or challenges in accessing water (IWMI, 2008a). The here presented model is based on a distinct example from Ghana and follows in its presentation a **hybrid of the business model and case templates**.

This example derives from Ghana's coastal region where farmers struggle with poor water quality and their irrigation infrastructure supports natural water remediation processes. Although risk reduction is not the main driver, the system supports the public interest in water (food) safety and forms a first step transition from informal to formal wastewater use. The farming site is located between several smaller, essentially temporary streams, which feed into the Sakumo lagoon in the densely populated

Accra-Tema mega-polis of Southern Ghana. There is very limited sewerage and wastewater treatment in this suburb and the streams carry highly polluted water from a wider urban catchment area, generated by households, trade and small industry. Since 1992, the 1360 ha wetland area around the lagoon is protected under the Ramsar convention[1]. About 414 ha of the land are used for irrigating traditional vegetables, with increasing shares of rainfed maize in the rainy season. The informal irrigation system as designed by the farmers combines gravity flow (also by blocking streams), canals or PVC pipes, and smaller storage ponds (dugouts), as well as portable water pumps. The system is designed to reduce the burden of carrying water over longer distances. Based on farmers' original efforts of creating storage facilities, the local community based NGO Friends of Ramsar Site (FORS) suggested in 2011 to upgrade the created canals and ponds into a designed natural treatment system. Farmers invested labor and cash to the tune of USD 3,600 while FORS secured from UNEP an additional amount of about USD 13,200 to upgrade the system with four smaller constructed wetland lagoons. Currently, more than 200 farmers are settled around the site, supported by a much larger number of seasonal labor. It is estimated that farmers generate a gross revenue of about USD 200,000 annually from the production of crops on the overall site with a high benefit-cost ratio[2]. As only a section (max. 30%) of the farmers was able to connect to the treatment system, FORS plans its extension. This has, however, to be accompanied with awareness creation on health risks, for farmers and consumers, to create more market demand for safer produce as further incentive for the farmers to engage in the innovation. In 2014, due to severe flooding and damage of infrastructure, the system stopped functioning and was still not operational again early 2017.

KEY PERFORMANCE INDICATORS OF THE CASE IN GHANA (2014)						
Land use:	414 hectares (1022 acres) of irrigated land of which about 30% were connected to the treatment system in 2012/13					
Water treated:	0.6–1.2 million cubicmeter (MCM) per year assuming 1–2 60-day cropping cycles					
Capital investment:	Ca. USD 16,800					
Labor requirements:	12–20 people needed for dredging (dredging done 2–3 times a month)					
O&M:	Up to USD 1,200 per season distributed over the local farmer association					
Output:	Partially treated wastewater for irrigation and in part livestock watering					
Potential social and/ or environmental impact:	With the planned extension up to 200 crop farmers (80–90% men) and an estimated 400 seasonal laborers (60% women) could benefit from access to partially treated water. The production of safer food benefits consumers in Tema and Accra, especially for food items eaten uncooked, and the overall site which as a traditional as well as tourist value					
Viability indicators:	Payback period:	N.A.	Post-tax IRR:	N.A.	Gross margin:	N.A.

Context and background

Due to limited wastewater collection and treatment, urban streams are across sub-Saharan Africa heavily polluted and mostly conveying domestic greywater, solid waste but also overflow from septic tanks, pushing especially pathogenic water quality indicators far above acceptable levels. The poor water quality is an increasing burden for farmers who depend on irrigation, as well as the environment as also shown on the example of the Sakumo Lagoon (Asmah et al., 2008; Agbemehia, 2014) near Accra. This wetland of international importance, which was declared in 1992 as a Ramsar site[3], covers an area of about 1,360 hectares and is situated between Ghana's capital city and Tema in the Greater Accra Region of Ghana. The size of the open lagoon varies between 100 and 350 hectares depending on the season. Four sub-basins are supporting the freshwater supply of the site: the major ones, named after their streams, are the Mamahuma and Onukpa Wahe (at the western side) and the

Dzorwulu and Gbagbla-(An)konu (situated at the northern end). The Eastern and Southern subbasins constitute minor inflows. The main feeder streams, the Dzorwulu and Mamahuma have been dammed upstream of the Ramsar site and re-channeled for local irrigation, such as the Dzorwulu stream which supports the well-known Ashaiman reservoir and irrigation scheme. The damming has resulted in very little influx of freshwater, that especially during the dry season wastewater dominates the flow. The streams are draining a wide urban catchment area capturing mostly domestic wastewater and storm water, but also effluents from lighter industry.

Ramsar administrative authority in Ghana is the Wildlife Division of the Forestry Commission. Farming and fishing are permitted and date back as long as farmers can recall. In 2010, the local farmer association '*Resource Users Association'* invested major efforts in improving water access, especially in the dry season, including a larger storage pond which can be connected to several farms. Farmers contributed labor and USD 3,600 in cash. In a subsequent development, the Friends of Ramsar Site (FORS), a non-profit organization, mobilized about USD 13,200 from UNEP to upgrade the treatment potential of the canals and pond system the farmers put in place via constructed wetlands (lagoons). The potential for high synergies between infrastructure in farmers' interests and natural pathogen elimination have been described for other sites in Accra by IWMI (2008a,b) and by Keraita et al. (2014), which offers a possible pathway in support of a gradual transition towards safer wastewater irrigation as supported by WHO (2006).

There are about 600 ha under farming of which around 414 ha are irrigated by at least 200 farmers supported by about 400 seasonal laborers. The major crops grown include fresh vegetables such as cucumber and green pepper, local vegetables (like okra, pepper, onion, tomatoes, ayoyo) and maize that are all in high demand in Accra. About 30% of the farmers were so far connected to the natural treatment system while the majority continues using untreated wastewater, but there are plans by FORS to increase the number of users by expanding the treatment system. The type of water used by farmers still depends mostly on convenience and pumping costs, not on risk awareness. Urban farmers are generally more concerned with visible trash (e.g. plastic) in the water while missing knowledge of invisible contaminants (Keraita et al., 2008). However, farmers at Sakumo indicated that the appearance and bad smell sometimes emanating from the wastewater is a challenge to them that they stopped irrigating a few days before harvest[4]. Sensory attributes such as the crop appearance, neatness and size rather than possible invisible health risks are also common among traders and consumers and reflect the common educational status (Keraita and Drechsel, 2015).

The Sakumo area received annually about 800 mm rain and has high educational (e.g. bird watching) and recreational value, being one of the few 'green' areas left in the rapidly expanding Accra-Tema metropolitan area. The lagoon is moreover regarded as a fetish by the local people and the local Black Heron bird is considered sacred.

Macro-economic environment

With an upsurge of both wastewater generation and irrigated urban farming, options which can increase produce and farmers' safety are needed across sub-Saharan Africa.

Urbanization and the growing urban demand for food are driving year-round food production which requires irrigation in the dry season(s). While some crops can be produced in irrigation schemes in rural areas and with safe freshwater, other crops are easily perishable and urban proximity is favored due to the lack of cold transport and storage but also as shorter food chains give financial advantages. However, urban proximity has also disadvantages. As at least 80% of the wastewater generated in Ghana's urban centers is released into the environment in its untreated form, making it nearly

impossible for farmers to find any unpolluted water source (Drechsel and Keraita, 2014). Groundwater access could be one option but seldom in ocean vicinity and also not at Sakumo (Agyepong, 1999). In Ghana, there are no data to tell where along natural streams contamination levels exceed irrigation thresholds. Without ability to monitor water quality or offer farmers a viable alternative, irrigated urban farming with its obvious benefits but also health risks remains in a state of "laissez-faire" without enforced restrictions or serious assistance (Drechsel et al., 2006; Drechsel and Keraita, 2014). The national irrigation policy (MoFA, 2011) permits safe wastewater use in line with the 2006 edition of the WHO-FAO-UNEP water reuse guidelines which demand for situations without treatment plant alternative risk barriers from 'farm to fork' (Amoah et al., 2011). The importance of urban farming in this context should not be underestimated: Lydecker and Drechsel (2010) estimated that in Accra more wastewater is 'treated' on-farm than in designated treatment plants.

Business model

The business is run by the Resource Users Association, a commercial farmers group producing crops for the local market. The value proposition of their and FORS co-investment is improved water access combined with reduced health risk despite the use of polluted irrigation water (Figure 273). Although the initial main driver of this business model was to access water for irrigation all year around, the private sector-NGO partnership added the safety objective.

The drive to get access to water has catalyzed farmers to invest jointly in the pond and canal system, a system which supports natural water remediation processes and can easily be combined with further safety enhancing features (cf. IWMI, 2008a,b; Keraita et al., 2014). The partnership with FORS created a win-win situation whereby the irrigation water receives a pre-treatment, farmers who like to join the association get access to water also in the dry season, and consumers are a step closer to safer food. The farmer association can be considered as owners of the wastewater treatment system as they invested both cash and labor for the construction of the system and are paying for its O&M costs. The farmers' association is now registered in the registrar general and has a constitution which explains the responsibilities of each member with regards to the wastewater treatment system[5]. The cost to maintain the system are borne by farmers as the situation arises, i.e. they don't pay regular fees for using the water but when there is a need, farmers are required to contribute. This is the case after seasonal flooding when the self-made dams blocking the river are commonly destroyed. If the farmer fails to contribute, the association will give a warning to the farmer to make the payment.

Normally, farmers understand that if the system does not work, they will not be able to get water. But in instances where a farmer fails to contribute to the maintenance of the system, the association can seize the farmer's water pump.

Value chain and position

The Ramsar wetland is used for different productive uses such as for crop farming, livestock rearing and fishing (Figure 274). Initially farmers had no alternative to using highly polluted stream water. An alternative option was created by the Resource Users Association and FORS which enabled farmers to use partially treated wastewater, and the lagoon to receive less floating debris. Although so far not all farmers at the Ramsar site can connect to the treated wastewater and traders still receive crops produced with untreated water, there are plans by FORS to increase the number of users by expanding the treatment system.

FIGURE 273. BUSINESS MODEL CANVAS – FARMERS' INNOVATION AS DRIVER OF CHANGE

KEY PARTNERS

- Friends of Ramsar Site (FORS)
- Environmental Protection Agency (EPA)
- Wildlife division
- UNEP
- Ministry of Food and Agriculture (MoFA)
- Local community of Sakumono
- Research partner or technical advisor

KEY ACTIVITIES

- Installing and maintaining a water storage cum treatment facility
- Advocacy by FORS
- Ensuring that farmers adhere to rules stipulated in the farmer's association's constitution

KEY RESOURCES

- Diluted wastewater
- Technical expertise
- Constructed wetland
- Macrophytes for natural water treatment
- Financing, labor

VALUE PROPOSITIONS

- Year-round access to safer water for irrigation than so far available

CUSTOMER RELATIONSHIPS

- Formal relationship between farmers and the farmer association
- Personal relationships with crop buyers (traders), indirect with consumers

CHANNELS

- Direct use of wastewater by farmers
- Depending on crop direct marketing or on-farm sale of produce

CUSTOMER SEGMENTS

- Farmers cultivating irrigated crops
- Public/authorities calling for safe produce
- Crop traders

COST STRUCTURE

- Capital investment by the Resource Users Association
- Capital investment by FORS
- Operation & Maintenance cost by farmers

REVENUE STREAMS

- Cash and in kind contribution by farmers for system set up and O&M; no payment for water from streams which is free in Ghana

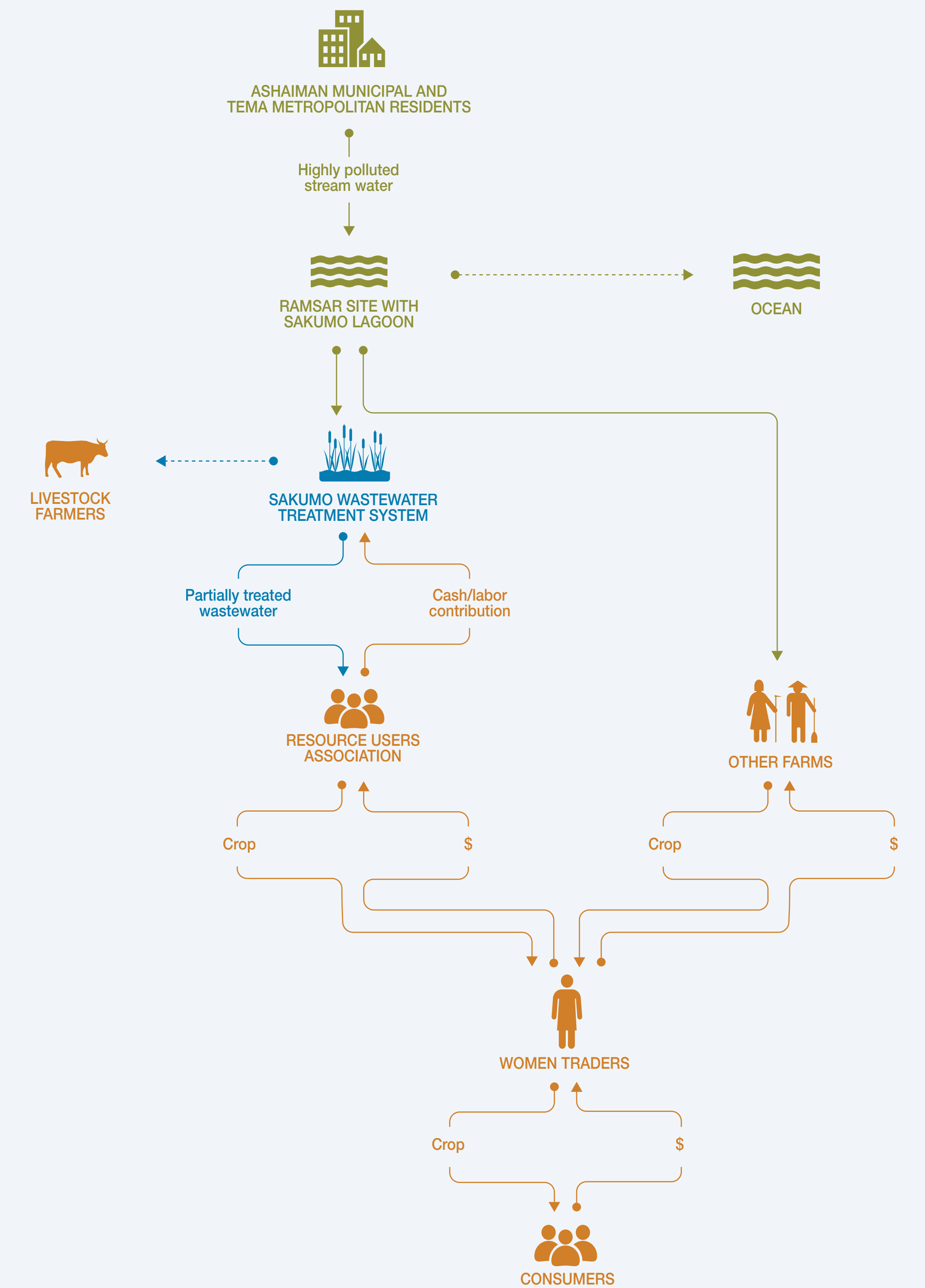
SOCIAL & ENVIRONMENTAL COSTS

- Possible increase in mosquito bites due to constructed wetlands (but as the whole area is a wetland, the added risk is marginal)

SOCIAL & ENVIRONMENTAL BENEFITS

- Compared with 'no intervention' possible risks to farmers, soils, crops and consumers will be reduced, but not eliminated
- Enhanced food security, possibility of connecting more farmers
- Partial removal of plastic waste which will benefit tourists and the local community around the main Lagoon

FIGURE 274. BUSINESS PROCESS FLOW AT THE SAKUMO FARMING SITE NEAR TEMA



Institutional environment

A set of policies and development plans provides the legal context for the institutional arrangements at the Sakumo Ramsar site near the community of Sakumono. The Ramsar site was created in 1992 by the legislative instrument (LI) 1659 and classified as an environmentally sensitive area under the Ghana Environmental Assessment (EA) regulation, legislative instrument (LI) 1652 of 1999. The National Land Policy of 1999 allows for the agricultural cultivation of wetlands provided its productivity is sustained. The Ministry of Local Government and Rural Development under the Ghana National Urban Policy Action Plan of 2012 recommends the development and use of open spaces, green belts and ecologically sensitive areas for urban farming. The common use of 'wastewater' in this context has been acknowledged in Ghana's National Irrigation Policy, Strategies and Regulatory Measures which recognized the relevance of the informal irrigation sector, and recommends compliance with the WHO (2006) wastewater use guidelines. Guidelines for the protection of the wetland are given in Ghana's National Wetlands Conservation Strategy and Action Plan (2007–2016).

The various institutions involved at the site and their roles include:

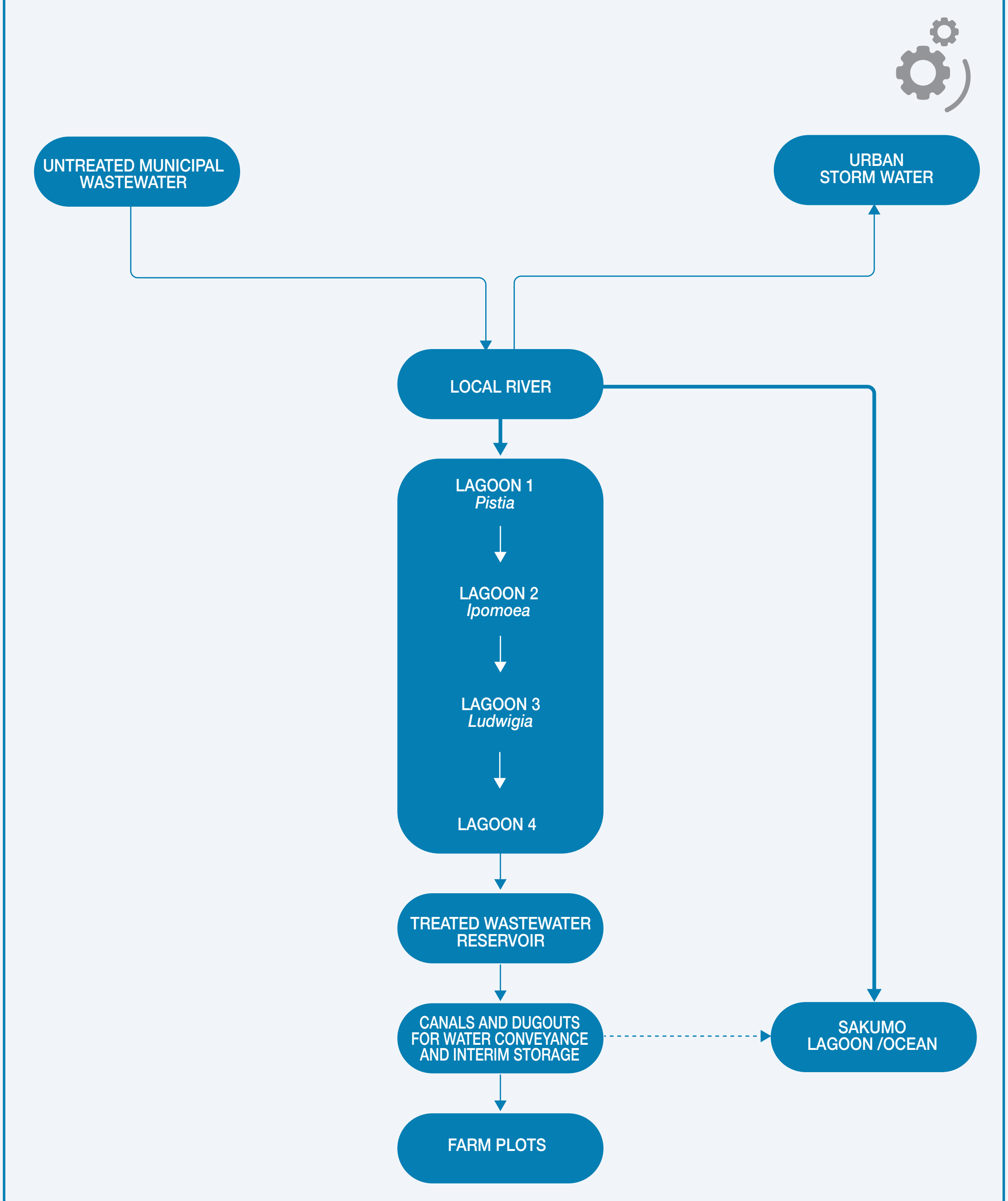
- *The Wildlife Division of the Forestry Commission under the Ministry of Land Forestry and Natural Resources* – responsible for the management of the Ramsar site, and helps to resolve conflicts between resident and seasonal farmers.
- *The Environmental Protection Agency* – responsible for monitoring and preventing of the pollution from the surrounding areas also as the Ramsar site is officially an environmentally sensitive area[6].
- *Tema Metropolitan Assembly* – is the city authority responsible for enforcing laws/bylaws and legislations concerning the site.
- *The Ministry of Food and Agriculture* – provides extension services to the farmers to guide and provide advice on agricultural input use and farming practices.
- *Resource Users Association* – a farmer association which had in 2014 about 75 members (13% women) use partially treated wastewater for irrigation at the site and which contributed in the construction and maintenance of the treatment system[7].
- *Friends of Ramsar Site* (FORS) – a non-governmental organization and advocacy group that helped to construct the wastewater treatment system, is responsible for its management and actively lobbies for the protection of the Sakumo site.
- *UNEP* – co-funded the construction of the wastewater treatment system and local tree planting[8].
- The surrounding communities such as Klagon, Sakumono, Community 3 and 19, and Nungua; their assemblies and traditional chiefs.

The local NGO FORS plays in this case a prominent role as broker between the different parties. However, for any replication of the case, FORS represents only one of many opportunities of local communities to engage and support their wetland and open farming areas in an urbanizing environment based on their various direct and indirect benefits (see also Lydecker and Drechsel, 2010).

Technology and processes

The water treatment at the Ramsar site (Figure 275) is based on natural processes (pathogen die-off, sedimentation, nutrient uptake, physical barriers, ...) where stream water is temporarily blocked and redirected through channels to four treatment ponds (100m^2 lagoons). The macrophytes *Pistia* (water lettuce), *Ipomoea* (water spinach) and *Ludwigia* (water primrose) are growing in the first three lagoons respectively while the fourth lagoon exposes the polluted water to sunlight. Eventually the water flows into a reservoir from where it is pumped onto the farms while excess water flows through a canal into the Sakumo lagoon and then into the sea. From time to time, the macrophytes are harvested and composted to fertilize the soil.

FIGURE 275. TREATMENT PROCESS DESIGN FOR WASTEWATER REUSE IN SAKUMO RAMSAR SITE NEAR TEMA, GHANA



First laboratory data showed that the system could be improved (retention time etc.) to increase the treatment quality. On another site in Accra at La, a farmer based cascade of small reservoirs showed a positive impact on pathogen levels (IWMI, 2008a). FORS is actively seeking collaboration with research institutions to optimize the system.

There are other examples, e.g. from India, showing how typical irrigation infrastructure can support water treatment processes, in particular the removal of pathogens (Ensink et al., 2010).

Funding and financial outlook

The generated capital investment for the wastewater treatment system was about USD 16,800, contributed by farmers and FORS. The investment took place in three phases:

- In 2010 a total of about USD 700 and labor for dredging was contributed by farmers.
- In 2011 about USD 2,900 was contributed by the farmers.
- In 2011 UNEP provided funding of USD 13,200 via EPA to FORS to work on the treatment ponds.

Maintenance of the system is done by the farmers. Dredging and removal of floating waste takes place two to three times a month depending on how chocked the system is, which varies between seasons. To dredge, 12–20 farmers work together. In addition to dredging, sacks are filled with sand to divert wastewater from the main river course into the constructed lagoons. Farmers estimated that about 150 sacks priced at USD 0.50 per sack are needed (i.e. total USD 75). Following heavy rains, the man-made dams usually need repair or reconstruction, and this is done three to four times a month. Over four months of rain, maintenance costs can exceed USD 1000. The contribution to maintain the wastewater is done by farmers as the situation arises, i.e. regular fees are low but when there is a need to work on the system, farmers are required to add additional money, with differences on where one's farm is located, i.e. how much farmers benefit. Farmers who were interviewed confirmed that despite these investments, their returns are multiple times higher than their costs[9].

In June and July 2014, severe flooding and sedimentation damaged the system, and its operation was paused[10]. A revised treatment system has been proposed by FORS to expand the present capacity of treatment and also improve the efficiency of the system. The new design will expand the size of the planted lagoons and intends to increase the share of water flowing by gravity to individual farms instead of being pumped. Buying or renting portable pumps also increases the initial investment of farmers especially those whose farms are located farther away from the treatment lagoons on top of investing in PVC pipes which can reach USD 500.

In an attempt to protect the site, improve the revenue streams and also maintain the ecology of the site, FORS in collaboration with UNEP and EPA has planted about 1,500 coconut seedlings at the site.

Socio-economic, health and environmental impact

Most of the farmers operating on the open wetland area practice commercial agriculture and produce fresh vegetables and cereals for sale in the city. The availability of water throughout the year gives them a competitive advantage. Although 90% of the about 200 farmers are men, more than the same number of women find employment as field workers for planting, weeding and harvesting; and women dominate trade and retail of most perishable vegetables.

The use of highly polluted water poses risks to farmers and consumers, and the initial mitigation measures by farmers are only one step on a longer journey. A microbial risk assessment estimated a possible loss of about 12,000 disability-adjusted life years (DALYs) annually in Ghana's major cities through the consumption of salad prepared from wastewater-irrigated lettuce (Drechsel and Seidu, 2011). This figure represents nearly 10% of the World Health Organization (WHO)-reported DALY loss occurring in urban Ghana due to various types of water, sanitation and hygiene-related diarrhea. Thus, the shift to partially treated irrigation water has been appreciated although more awareness creation on health benefits is needed to establish a related "safer food" value chain where premium prices make investment and behavior change of traders worthwhile (Keraita and Drechsel, 2015). So far, farmers

appreciate the increased water proximity, storage and separation of solid waste more than possible health benefits. However, farmers also indicated their support for treatment measures improving the smell of the water. Farmers' willingness to invest in better water was also confirmed by Amponsah et al. (2016) in Kumasi (Ghana) showing that 60% of surveyed open space commercial vegetable farmers were willing to pay for reclaimed water for irrigation.

Women traders who were interviewed appreciated farmers' efforts at Sakumo as it has created a good image that the vegetables are cleaner. However, this does not prevent traders from mixing vegetables produced under safer and unsafer conditions. More consumer awareness is needed as well as public controls to keep the two value chains separate. The investment would pay off as every USD spent in on-farm treatment and post-harvest safety returns up to USD 4.9 in public health cost savings (Keraita et al., 2015).

Farmer support of waste management in this area will have benefits beyond the farms. The wetland provides valuable products and services, which include the provision of important spawning and nursery grounds for many fish species. It is absorbing floodwaters and protecting biodiversity. The wetland also serves as roosting, nesting and feeding sites for many species of birds (Entsua-Mensah et al., 2000). The site is rated the third most important for seashore birds along Ghana's coast. More than sixty bird species have been identified including six internationally important species.

Scalability and replicability considerations

Farmers' innovation capacity is well known (Reij and Waters-Bayer, 2001) and has been reported also from other countries where wastewater irrigation is common (Buechler and Mekala, 2005). The innovation requires relatively low investment costs and can easily be replicated on similar (peri)urban farming sites. Depending on the scale of local risk awareness, capacity development and further incentives would be supportive. The key drivers for the Sakumo case are:

- A business advantage for farmers to engage (as an organized group) in on-farm intervention, driven in this case by their desire to channel the water closer to their plots, create storage facility for periods of low flow, filter floating (plastic) debris, and remove bad water smell. A very similar situation exists, e.g. on the La farming site in Accra.
- An advantage for the local community interested in the protection and image of their wetland which has both a traditional role as well as a potential value for recreation and tourism (bird watching), and the formation of a related interest group (FORS) supporting the farmers.
- An enabling environment where policies, authorities and international agencies are supportive of the community efforts.
- A favourable cost-benefit ratio based on the additional cultivation area (and less production risks).
- Knowledge on technical options able to link farmers' interest with water quality treatment.
- Sense of ownership of the infrastructure by farmers and willingness to contribute to its O&M.

This business case presents a low-cost effort where simple technology provided a first step towards safer water reuse and there are more irrigation infrastructure options, in particular weirs (Ensink et al., 2010), which support natural remediation processes, independently if implemented with or without risk awareness.

However, to maintain and extend the treatment process, risk awareness supported by demand for safer food would be helpful. Value chains linking to dedicated outlets, like particular 'food quality' markets could be a start. The model would also gain in sustainability if EPA or MoFA could regularly monitor water quality and support farmers and traders complying with on- and off-farm safety protocols. The WHO (2015) *Sanitation Safety Planning Manual* provides a framework for such a process, which will facilitate further up- and out-scaling.

Potential risks and mitigation

In designing any business model, it is assumed that generic business risks are known and will be taken care of. However, some risks might be more model specific and will be acknowledged in the following:

Market risks: Like in the here presented case of Accra, most farming locations where wastewater is informally used are in close proximity to major urban markets and well positioned to respond quickly to market needs, save on transport costs, and deliver high-value crops also in the lean season when revenues peak. As crops produced with wastewater or freshwater are with few exceptions mixed in markets and risk awareness along the food chain is commonly low, market incentives for safe production remain limited, while urban demand for vegetables is high.

Competition risks: This is only possible where with increasing risk awareness along the food chain, the potential of competition from freshwater farmers is growing. So far this awareness is in most low-income countries limited and competition is stronger from the other end, i.e. farmers using raw wastewater without any investments (extra costs) in safety.

Technology and performance risks: The employed technologies are low-cost and mostly based on manual work, where one-time or seasonal investments in irrigation infrastructure pay off through reduced operational (labor) costs. As wetlands in coastal areas also function as buffer for flooding, the system has to withstand flash floods.

Political and regulatory risks: A significant challenge can come from the regulatory framework if this is not supporting. While in Accra, the use of wastewater for crop production is forbidden by local byelaws, Ghana's national irrigation policy is supporting the WHO (2006) guidelines which recommend a step-wise approach to move towards safer wastewater irrigation (Drechsel and Keraita, 2014).

Social equity related risks: The share of men and women in the informal irrigation sector differs between countries and cultures from mostly female, e.g. in Sierra Leone, to mostly male, e.g. in

TABLE 64. POTENTIAL HEALTH AND ENVIRONMENTAL RISK AND SUGGESTED MITIGATION MEASURES FOR BUSINESS MODEL 24

RISK GROUP	EXPOSURE					REMARKS
	DIRECT CONTACT	AIR/ ODOR	INSECTS	WATER/ SOIL	FOOD	
Farmers						After introduction of farm based risk reduction measures, their adoption has to be monitored
Community						
Consumer						
Mitigation measures				Pb Hg Cd	Pb Hg Cd	

Key: NOT APPLICABLE · LOW RISK · MEDIUM RISK · HIGH RISK

Senegal (Drechsel et al., 2006). There is no difference in innovation capacity although some of the innovations are very labor intensive. In the presented case study, both gender are equally presented within the overall value chain from farm to market.

Safety, environmental and health risks: The model follows the WHO (2006) recommendation of a step-wise and stakeholder inclusive approach to risk mitigation which is an intermediate step until (a) more comprehensive wastewater collection and treatment systems are in place; and (b) stricter safety guidelines can be implemented and enforced. In this sense, there are significant risks remaining – although less than without farmers' innovative efforts – which need to be controlled (Table 64). While pathogen loads can be reduced through on-farm treatment, other health risks will not be eliminated and additional preventive measures are required.

SWOT analysis and business performance

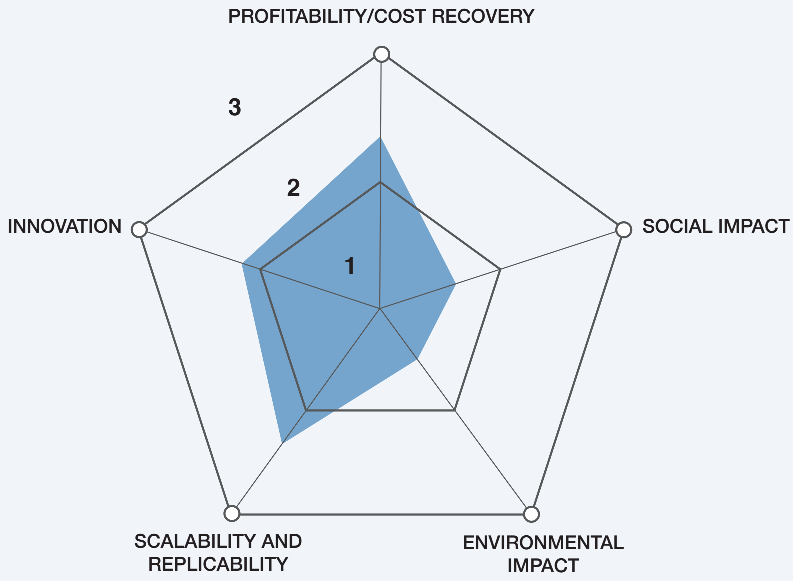
While this business case focused originally on supporting urban agriculture with better access to irrigation water, the installed pond system has the potential to improve also water quality and food safety. If combined with awareness creation and monitoring, incentives can be created to expand the system to progress gradually from informal to formal wastewater use. Similar synergies between

FIGURE 275. SWOT ANALYSIS OF SAKUMO WASTEWATER TREATMENT CASE, GHANA

	HELPFUL TO ACHIEVING THE OBJECTIVES	**HARMFUL** TO ACHIEVING THE OBJECTIVES
INTERNAL ORIGIN ATTRIBUTES OF THE ENTERPRISE	**STRENGTHS** ▪ Strong farmer's association with formal rules ▪ Willingness of farmers to invest in the set-up and maintenance of the treatment system ▪ Partnership with an NGO (FORS) able to advocate farmers interest and leverage funds ▪ Involvement of different institutions such as EPA, Forestry commission, UNEP, local chiefs ▪ Low O&M cost and the system can easily be upgraded ▪ Higher safety than in a business-as-usual scenario	**WEAKNESSES** ▪ The achieved treatment level is only an initial step in the right direction ▪ Farmers are more concerned with visible trash (e.g. plastic blocking pumps) than pathogens in the water, and might bypass designed treatment process ▪ Difficulty in expanding the scheme in the region due to only emerging 'safe food' awareness and marketing ▪ Inadequate monitoring of water quality to verify/improve treatment quality ▪ System reconstruction requires resources if severely damaged through flooding
EXTERNAL ORIGIN ATTRIBUTES OF THE ENVIRONMENT	**OPPORTUNITIES** ▪ Treatment system addresses demands related to water quantity and quality ▪ Opportunity for higher yields/extra harvest ▪ Environmental benefits from reduced trash and wastewater in the Sakumo lagoon ▪ New revenue option for (male) farmers and (female) traders based on increasing awareness for food safety ▪ Farmers' occupational health risks are controllable	**THREATS** ▪ Despite multiple strong stakeholders, and public interest in food safety, no institution accepts so far responsibility to assist farmers regularly ▪ Remaining crop contamination risks ▪ Remaining farmer exposure ▪ Urban encroachment on the site ▪ Septage operators dumping raw sludge into the wetland and wastewater inflow continues to increase ▪ Flooding destroying nature based treatment ponds

private and public interests are possible in view of the timing of irrigation (see above) and other farming practices (IWMI 2008a, b). This creates potentially a win-win situation whereby the city's wastewater undergoes a first treatment and farmers get access to more and safer irrigation water than without the intervention, resulting in higher returns and relatively safer food for consumers than in a business as usual scenario. However, the Sakumo water treatment system will not eliminate health risks and other risk mitigation measures have to be added between 'farm and fork' (Amoah et al., 2011). Figure 275 shows the SWOT analysis for the business case, while Figure 276 shows the impact potential of a farmer innovation model for increasing food safety.

FIGURE 276. IMPACT APPRAISAL FOR A FARMER-INNOVATION BASED BUSINESS MODEL FOR INCREASED FOOD SAFETY



As the model is only a building block on the trajectory from unsafe to safe wastewater use, its impact remains modest. Although the technical innovation is down to earth, the effort to create a win-win situation between farmers' initial interests and safeguarding public health is very innovative. Where this engagement can be supported, the model will rank well in view of scalability and replicability without undermining the profitability of the business for farmers (Figure 276). The cost-benefit balance might shift through the introduction of more advanced and capital or maintenance intensive on-farm technologies. Thus, any replication or expansion should be aligned with the support of a value chain which targets (the increase of) market segments cherishing food safety.

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Case and model descriptions are based on primary and secondary data provided by case operators, insiders or other stakeholders, and reflect our best knowledge at the time of the assessments 2015. As business operations are dynamic data are likely subject to change.

Notes

1 www.ramsar.org/about-the-ramsar-convention (assessed 4 Nov. 2017).
2 GTV news video (www.youtube.com/watch?v=CGZVW4nb7cc; assessed 4 Nov. 2017).
3 https://rsis.ramsar.org/ris/565 (assessed 4 Nov. 2017).
4 This is an interesting example where farmers changed behavior, probably to avoid traders to reject their 'smelly' produce, which in fact supports the natural die-off of pathogens as recommended by WHO (Keraita et al., 2007).
5 As an association, farmers have an increased ability to offer traders a higher and more reliable supply at lower contracting costs (one-stop-shop). Moreover, a registered association can easier access agricultural loans and possibly use its cooperative capital as collateral for fund raising.
6 While the protection of the wetland has to start upstream where pollution is generated, EPA struggles with the lack of sewage collection and treatment.
7 In 2014, the Resource Users Association and local fishermen registered as an official association under the companies act and the name of "Sakumo Ramsar Conservation and Resource Users Association". www.ghananewsagency.org/social/users-of-sakumo-wetland-form-association--76109 (assessed 4 Nov. 2017).
8 Ghana's Environmental Protection Agency (EPA) and the United Nation Environment Programme (UNEP) initiated in 2013–2014 an afforestation project of planting mangoes and coconuts in the wetland area. The trees should provide income and prevent further encroachment and land degradation.
9 See also www.youtube.com/watch?v=CGZVW4nb7cc (assessed 4 Nov. 2017).
10 Famers continued using the treatment infrastructure for their own advantage, including abstracting water also from the treatment lagoons nearest to their farm. At the time of writing in late 2016, FORS was still seeking support for system repair and extension.