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CASE

Fixed wastewater-freshwater swap (Mashhad Plain, Iran)

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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Farmers' cooperation was facilitated by providing 1.2 times more replacement water than what was withdrawn.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.

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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

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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.

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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

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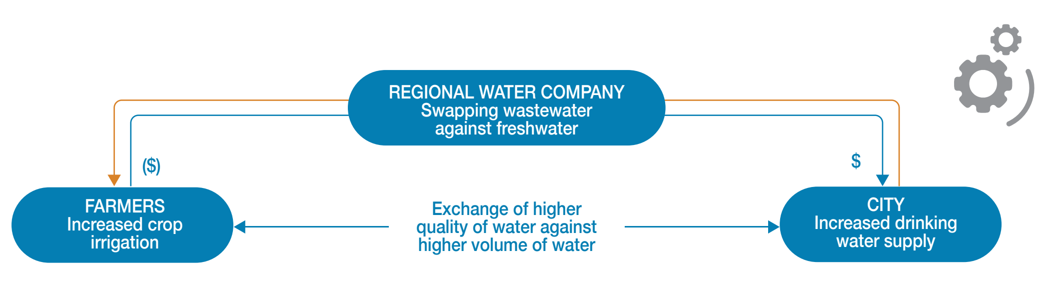
B) Individual contracts between the Regional Water Company and the (larger) individual water right owner based on the right of every single water user.

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).

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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

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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

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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.