CASE

Suburban wastewater treatment designed for reuse and replication (Morocco)

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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 2,700m³ per day (design capacity 600–1,000m³ 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 800m³ 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/m³ 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)

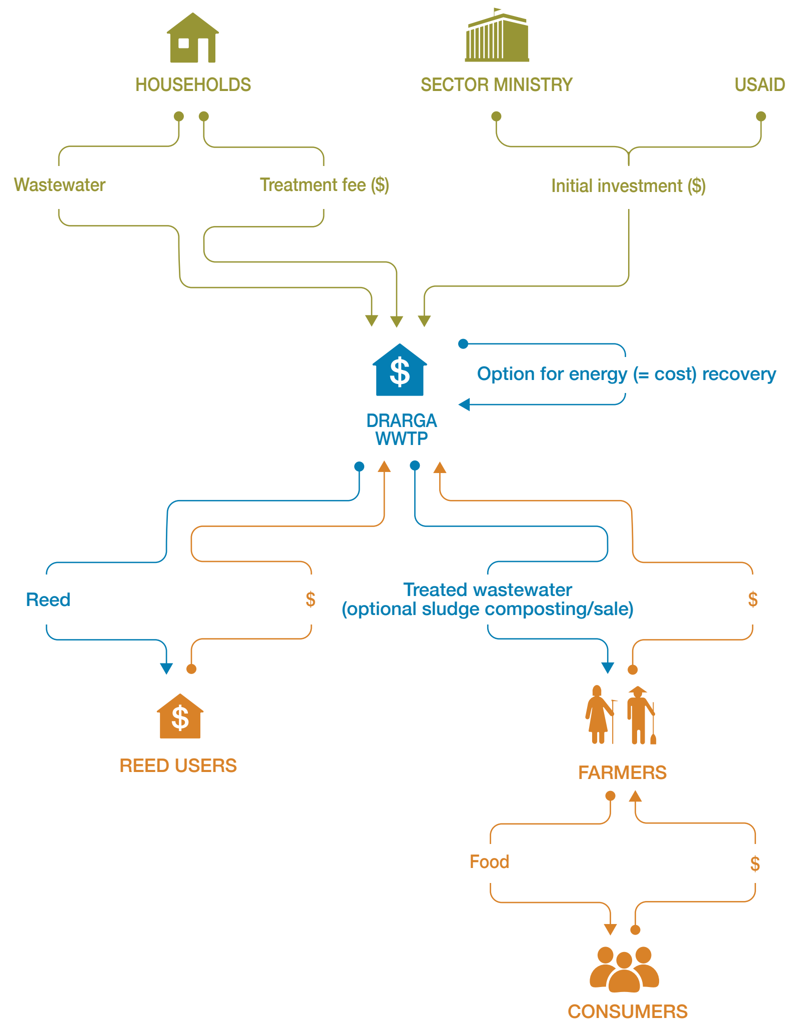
REVENUE STREAMS
- Household sewage fees
- Sale of wastewater, reed, co-compost (optional)
- Energy recovery (optional)

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

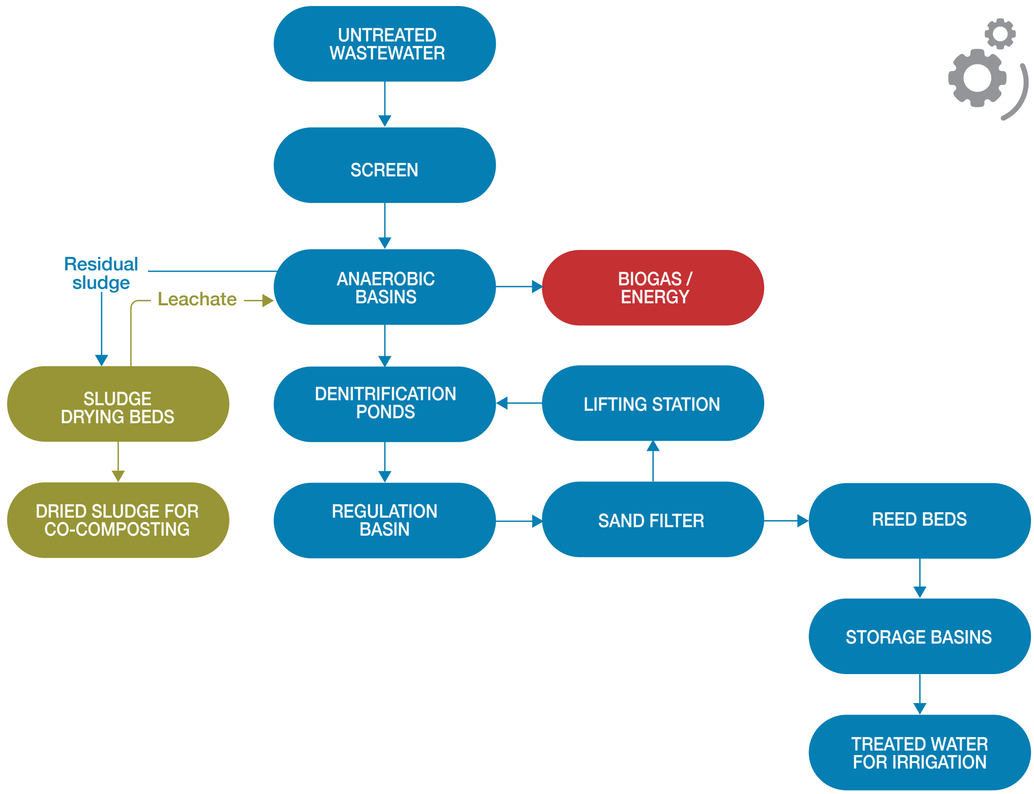
The plant provides advanced wastewater treatment with limited energy demands. After initial wastewater screening and grit removal, the wastewater is treated in two 918m^3 anaerobic basins with an average hydraulic retention time (HRT) of about three days. The flow is then sent to two 736m^3 denitrification 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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References and further readings

Aomar, J. and Abdelmjid, K. 2002. Wastewater reuse in Morocco. Paper presented at the Water Demand Management Forum. Ministry of Agriculture, Rural Development and Waters and Forests. www.hitpages.com/doc/4664231974666240/1.

Bahri, A. 2008. Water reuse in Middle Eastern and North African countries. In: Water reuse: An international survey of current practice, issues and needs. Jimenez, B. and Asano, T. (eds). ISBN: 9781843390893. London, UK: IWA Publishing. Scientific and Technical Report. No. 20. pp. 27–47.

Choukr-Allah, R. and Hamdy, A. 2005 Best management practices for sustainable reuse of treated wastewater. In: Hamdy A. et al. (eds.), Non-conventional water use: WASAMED project. Bari: CIHEAM / EU DG Research, pp. 191–200 (Options Méditerranéennes: Série B. Etudes et Recherches; n. 53).

Choukr-Allah, R., Thor, A. and Young, P.E. 2005. Domestic wastewater treatment and agricultural reuse in Drarga, Morocco. In: Hamdy A. et al. (eds). Non-conventional water use: WASAMED project. Bari: CIHEAM /EU DG Research, pp. 147–155 (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 66).

Dadi, E.-M. 2010. L'évaluation de la possibilité de réutiliser en agriculture l'effluent traité de la commune de Drarga. Master thesis at Université de Sherbrooke. http://savoirs.usherbrooke.ca/handle/11143/7134 (accessed 5 Nov. 2017).

Environmental Alternatives Unlimited (EAU). 2002. Water resources sustainability project (WRS). Marketing strategy for Drarga wastewater and reuse pilot project. Report for USAID. Contract No. 608-0222-C-00-6007-00. http://pdf.usaid.gov/pdf_docs/PNACW910.pdf (accessed 5 Nov. 2017).

Environmental Alternatives Unlimited (EAU). 2004. Morocco water resources sustainability project final report. www.ircwash.org/sites/default/files/Morocco-2004-Morocco.pdf (accessed 5 Nov. 2017).

Hirich, A. and Choukr-Allah, R. 2013. Wastewater reuse in the Mediterranean region: Case of Morocco. Daniel Thevenot (ed). 13th edition of the World Wide Workshop for Young Environmental Scientists (WWW-YES-2013) – Urban waters: Resource or risks? Jun 2013, Arcueil, France. https://hal.archives-ouvertes.fr/hal-00843370/document (accessed 5 Nov. 2017).

Houdret, A. 2012. The water connection: Irrigation, Water grabbing and politics in southern Morocco. Water Alternatives 5 (2): 284–303.

MEMEE. 2013. Stratégie Nationale de l'Eau en matière de protection et de développement de l'offre: Réutilisation des eaux usées épurées. Ministere de l'energie, des mines, de l'eau et de l'environnement. www.agire-maroc.org/fileadmin/user_files/2013-02-04-pnarr-rabat/1/2013-02-04-Strategie-Nationale-Eau-Makhokh-Jaoucher.pdf (or https://goo.gl/96tWf1; accessed 5 Nov. 2017).

Mohamed, H.O. and Young, R. 2013. Environmental and economic impacts of using effluent of Drarga WTP for irrigating potato. International Journal of Chemical & Environmental Engineering 4 (1): 75–80.

Murray, A. and Buckley, C. 2010. Designing reuse-oriented sanitation infrastructure: The design for service planning approach. In: Drechsel, P., Scott, C.A., Raschid-Sally, L., Redwood, M. and Bahri, A. (eds) Wastewater Irrigation and health: Assessing and mitigation risks in low-income countries. UK: Earthscan-IDRC-IWMI. pp. 303–318.

Rijsberman, F.R. 2006. Water Scarcity: Fact or Fiction? Agricultural Water Management 80 (1–3): 5–22.

Salama, Y., Chennaoui, M., Sylla, A., Mountadar, M., Rihani, M. and Assobhei, O. 2014. Review of wastewater treatment and reuse in the Morocco: Aspects and perspectives. International Journal of Environment and Pollution Research 2 (1): 9–25. www.eajournals.org/wp-content/uploads/Review-of-Wastewater-Treatment-and-Reuse-in-the-Morocco-Aspects-and-Perspectives.pdf (accessed 5 Nov. 2017).

US EPA/USAID. 2004. Guidelines for water reuse. Washington, DC: U.S. Environmental Protection Agency (EPA/625/R-04/108).

Van der Hoek, W., Ul Hassan, M., Ensink, J.H.J., Feenstra, S., Raschid-Sally, L., Munir, S., Aslam, R., Ali, N., Hussain, R. and Matsuno, Y. 2002. Urban wastewater: A valuable resource for agriculture. A case study from Haroonabad, Pakistan. Research Report 63. Colombo, Sri Lanka: IWMI.

Young, T., Copithorn, R., Karam, J. and Abu-Rayyan, O. 2011. Reliable low technology for pollution control in semi-rural Morocco and Jordan. Water (Journal of the Australian Water Association) Dec 2011: 77–81.

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).