The role of policies and equal burden sharing in the ecological footprint of potable water production in Cyprus

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Abstract

Cyprus as a popular holiday destination has the pleasure of hosting over 2.3M tourists annually. But tourism has been a mixed blessing to an island that is struggling with droughts and subsequent water shortages. Water rationing has traditionally been the key policy attempting to limit consumption and promote conservation. This literally meant intermittent water supply and as little as one day of running water per week in some areas of the island. While the islanders had to cope with such a harsh rationing regime, tourists had access to continuous water supply causing inequality in burden sharing.

The government of Cyprus has attempted to tackle the issue of diminishing water supply, and the past decade saw the commissioning of two desalination plants. Introducing desalination has certainly alleviated the immediate threat of potable water shortages but at what cost? Even with the most effective technology, desalination is extremely energy intensive thus creating a large ecological footprint for potable water because electricity on the island is produced using heavy fuel oil with high global warming potential. In addition, it has been the government policy to subsidise water prices, which in turn means that the true costs of water production have not been passed to the end user. It is evident that under the EU legislation such subsidies cannot be continued indefinitely.

This paper aims to look at the energy intensity of potable water production and subsequently its ecological footprint in Cyprus. It is of particular interest to investigate how the tourism industry could bear its fair share in water conservation efforts thus providing a more equal basis for burden sharing. Subsequently, the role of water policies as a driver for water security will be examined in view of the EU framework.

1 Introduction

The economy of Cyprus is heavily dependent on its tourism revenue generated by over 2.3M tourists annually. With 854300 (2005) inhabitants, the visitors account for nearly three times the population. Needless to say, such an influx of people has an impact on the distribution of natural resources, water in particular, on an island that is subject to droughts and subsequent water shortages. Further, it is estimated that 21 percent of the island's potable water demands are attributed to tourism [1]. Water rationing has traditionally been the key policy attempting to limit consumption and promote conservation but the burden has been carried by the local population while tourists have had access to unlimited water supply.

This paper looks at the role of the tourism industry in water conservation in the context of the high ecological footprint of water production in a semiarid climate such as in Cyprus. Energy intensity of water production and related policy issues are discussed and an attempt is made to outline methods to promote water conservation and more equal burden sharing.

2 Water resources management

The colonial era saw the establishment of the current Water Development Department, then called the Water Supply and Irrigation Department, but it was not until the independence of the island in 1960 that the Department acting under the Ministry of Agriculture, Natural Resources and Environment was able to effectively undertake the water resources management. The task has been challenging and therefore a brief look at the past is provided in order to put the present and future policies in the correct historical context.

2.1 Historical review of water resources in Cyprus

Archaeological evidence on the island indicates that the earliest settlements date back to over 8000 B.C. to Stone Age and Neolithic era when human activity was concentrated near ground and surface water sources. Later settlements show structures used for rainwater harvesting. Further, the Classic, Hellenistic and Roman eras (480 B.C. to 49 A.D.) saw a more systematic development of water resources and distribution of water through manmade conveyance systems and aqueducts as large as 40 km in length. In addition, an underground chain of wells network was developed during the same period in order to distribute ground water for drinking and irrigation purposes [2].

Throughout the history of the island serious draughts have been recorded, some lasting so long that the island was nearly deserted. The many conquerors of the island have had to face the serious water shortage issue and remnants of their mitigation methods are evident until today.

The early assessment by the British colonialists in the late 1800s was that the topography of the island was not suitable for cheap dam construction. Subsequently, the overexploitation of groundwater sources got started and as a direct result, the water table has dropped and sea water intrusion into coastal aquifers has been observed.

Since the independence of the island in 1960 the government water policy has been: ‘Not a drop of water to the sea’ [2]. Large dam projects followed as a result of this philosophy and surface water storage capacity has been increased from a mere 6 Mm^3 in 1960 to 325.5 Mm^3 today.

Rapid economic development on the island, in particular tourism, starting from the 1980s once again faced the island with the harsh reality of water scarcity. Coupled with the general tendency of diminishing rainfall as observed for the latter half of the 20th century due to global climate change and a particularly dry decade of the 1990s, the government of Cyprus took a bold decision to resort to seawater desalination [3].

2.2 The drought years and subsequent conservation measures

During the 1990s Cyprus experienced particularly low rainfall, yet at the same time the total water demand on the island was in rapid increase. The first conservation measures taken by the government via the water authorities were limiting supply. In many regions water was available only twice a week for duration of 12 hours. Due to the fact that water supply has always been somewhat unreliable, all houses and public premises in Cyprus are equipped with a water storage tank that acts as a reservoir for no-supply days. However, the storage capacity was not originally designed to accommodate 3-4-day supply; a requirement suddenly imposed on the nation. This lead to upsizing tanks or installing second ones, which in turn partially defeated the efficacy of the restriction policy. This was particularly the case with hotels that could not afford lowering their service standard and instead had to store more. Regardless, overall domestic consumption reductions in the order of 17 percent were observed by Larnaca Water Board due to the restricted supply which equalled to 70 percent of the normal supply. The largest savings were experienced in the ‘non-revenue’ water, i.e. water that is either lost to the ground or due to inaccuracies in metering, which was reduced from an average of 25-28 percent to 13-16 percent. Initially such savings appeared attractive but the intermittent water supply soon generated other serious problems in the distribution infrastructure. The cyclic changes in water pressure and subsequent 'water hammer' phenomenon led to leakages in the piping. Furthermore, coastal pipelines became subject to salt water intrusion which is possible only when the pipeline is not under pressure.

The drought years were particularly hard on agriculture that totally relies on irrigation. Water for irrigation was similarly rationed and had a negative economic impact on the sector as a whole. Recycled water from sewage treatments plants has since been made available for irrigation purposes and many hotels in the Larnaca area can now take advantage of it for grounds irrigation.

To further enforce water conservation, legislation was put in place to reduce consumption. For example, a permanent hosepipe ban forbids the use of municipal water in hosing verandas and pavements and washing cars. In addition, symbolic subsidies are available for domestic measures taken to reduce dependency on municipal water supply. These include drilling a borehole for garden irrigation purposes, supplying toilet flushing from a private borehole and installing a grey water recycling system [4]. With the exception of grey water recycling systems, the incentives scheme seems to shift dependency from municipal water supply to groundwater sources, which as a concept is questionable due to the serious depletion of groundwater sources, as discussed earlier. Therefore, the incentives would be better directed towards measures that would yield net savings in consumption. Such measures could include grants for upgrading water fittings (low-flush toilets, efficient shower heads, A-rated washing machines and dishwashers, etc.) and rainwater harvesting systems.

Fines were applied to illegal hosepipe use on spot check basis. But such a method is labour intensive and rather ineffective. Water consumption in agricultural irrigation was controlled with quotas and fines for over-consumption and cutting off supply for persistent large quota overruns.

2.3 Current water distribution organisation and pricing policies

Water distribution on the island is currently handled by three water boards, namely Nicosia, Limassol and Larnaca, that are in charge of the larger urban areas. Other areas that consist of smaller villages and agricultural land are under the jurisdiction of municipal water authorities. The three water boards are obliged to follow pricing guidelines approved by the council of ministers whereas the municipal authorities are free to set their own tariffs. This means that there are notable differences in water prices on the island. Unit prices dictated by the government do not cover the costs associated with distribution and therefore the water boards are typically loss making or at the best struggling to break even. In areas like the capital city Nicosia, the recent new housing development has been extensive and has generated extra income to the Nicosia Water Board whereas Larnaca Water Board has not been able to reap any significant revenue from such new developments recently.

There are different tariffs for domestic and commercial water users. The government policy has been to keep the essential amount of water (up to about 15 m^3/mo/household) affordable for households whereas commercial customers are charged a higher price. Large consumers, such as hotels, are heavily charged particularly by the unregulated municipal authorities. For example, a household in the Pafos area can buy 302 m^3 of water for the same price that a hotel pays for the first cubic metre. This is due to high fixed fees imposed on commercial customers.

2.4 Future

The EU Water Directive 2000/60/EC (23-10-2000) establishing a framework for community action in the field of water policy [5] will have to be implemented on the island by 2010. In particular, the Article 9 that deals with the recovery of costs for water services dictates that water pricing will have to reflect the actual price of water production and distribution. The price shall take into account both the environmental and resource costs based on a sound economic analysis. The 'polluter pays' principle is to be embedded into the pricing and penalty structure.

In addition, the water pricing policies shall provide adequate incentives for consumers to use water resources efficiently and thereby contribute to the environmental objectives of the directive. Similarly, effective, proportionate and dissuasive penalties have to be adopted in case the national provisions of the directive are breached.

Currently, the desalinated water costs in particular are subsidised and the government selling price of €0.58/m^3 to the water boards barely covers the cost of electricity required for the operation[1]. In the context that energy costs represent about one half of the production costs [6], the other half accounting for the operation and maintenance of the plant, it is concluded that the selling price represents only 50 percent of the actual costs. Due to the fact that the desalinated water gets mixed in the network with water from surface sources for which the true price is lower, it is not straight forward to estimate the exact proportion of the subsidy. Nevertheless, it is of paramount importance to optimise water management so that at all times it meets the 'triple bottom line' criteria, i.e. balances economic, environmental and social demands.

3 Ecological footprint of water production

As stated earlier, groundwater sources in Cyprus have largely been exhausted and subsequently the major portion of potable and irrigation water is produced either by collecting rainfall runoff in dams or by seawater desalination. One of the aims of this study was to evaluate the energy component in dam construction and in desalination operation in order to derive the 'ecological price' of water in terms of CO_2 emissions produced. The largest dam, Kouris, was analysed. In addition, operational energy demands for the two desalination plants were investigated.

3.1 Dams

From the island's annual usable water balance of 370 Mm^3 about 32 percent is lost into the sea [4]. Therefore, dam building has been highly justified in implementing the 'not a drop of water to the sea' policy. There are currently 108 dams and water storage ponds in Cyprus and new ones under construction. However, dam construction is controversial to say the least. Although generally the socioeconomic benefits of dams outweigh their negative impacts, the price paid is high both in monetary and environmental terms. The World Commission on Dams (WCD) recognises that mistakes have been made in many projects [7] and that more careful planning and especially public participation are required to avoid such mistakes in the future. Environmental impacts associated with dam construction typically include issues related to loss and disturbances in local ecosystems, be it flora or fauna. The WCD also highlights the possibility of increased CO_2 emissions due to rotting biomass under water, although quantifying such emissions is difficult unless the preconstruction conditions in terms of carbon emissions or sequestration are known [8]. However, the actual dam construction that typically involves massive amounts of earth and concrete works, does not seem to be addressed. Therefore, an attempt was made as a part of this study to derive the embodied energy component of the largest dam on the island, Kouris Dam.

Kouris Dam was built between 1984-88. It is 110 meters high and has a storage capacity of 115 Mm^3. No detailed records of construction equipment hours or daily diaries were available due to the fact that the activities took place a long time ago. Therefore, the estimation exercise was rather difficult and perhaps not as accurate as desired. Nevertheless, the exercise clearly revealed the key issues and inherent problems in embodied energy estimation of dam construction.

The analysis was done according to the following methodology:

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[1] Average price of electricity is at €0.10 per kWh.

a) Excavation works:

Volumes given in the bill of quantities were assumed to be done by suitable equipment for which average production and fuel consumption figures were available. Total fuel consumption was subsequently converted into equivalent CO_2 emissions.

b) Earth fill works:

Extraction and loading activities in the borrow areas were evaluated as above using suitable equipment. Transportation to the dam site using dumper trucks was calculated based on measured delivery route distances. Spreading and soil compaction works were included.

c) Concrete works:

Embodied energy associated with concrete based on its compressive strength was determined based on available literature [9]. CO_2 emission equivalent of 0.3 kg of CO_2 per m^3 was assumed to represent energy expenditure in cement and aggregate manufacturing and related transport. In addition, transportation of ready concrete from the mixing plant to the site was added based on measured delivery routes.

d) Road works:

Energy in road works was estimated based on the road surface area and the associated base course and asphalt quantities using suitable equipment.

e) Miscellaneous items:

The difficulties in assessing the energy expenditure was culminated in items such as transportation of construction equipment, lighting, mobility of construction staff, etc. The contractor opted to transport some heavy construction machinery from overseas, as far away as from Venezuela resulting in transport distance of over 10300 km. In addition, the contractor's management team was located in Italy but made regular visits to Cyprus over the four years of construction naturally creating an air travel component (4000 km round trip). Furthermore, many of the local workers were travelling more than 100 km daily to and from work by car. Big bulk of the works was done in two shifts, i.e. 16-hour working days necessitating massive lighting arrangements for night time activities. In addition, the maintenance of the construction machinery adds a significant component into the operation costs and energy expenditure. For a frame of reference, a hydraulic excavator holds 600+ litres of oil that needs to be changed regularly. Similarly, tyre replacement can be substantial and it is to be noted that a truck tyre weighs around 55 kg [10] and its carbon footprint is over 270 kg of CO_2 due to raw materials only without considering manufacturing and transportation. Having in mind that truck tyres may have to be changed as often as every 1100 hours in severe operating conditions [11] which translates to five sets of tyres per year for a 2-shift, 6-day working week, the tyre factor clearly becomes significant. However, as no records were available for the studied dam, it was impossible to accurately quantify the contribution of such activities in the overall carbon footprint. Therefore, their contribution is discussed anecdotally only.

This study concentrated on evaluating the energy intensity of the civil works only. No attempt was made to estimate the embodied energy of the electro-mechanical equipment as their contribution was considered minor in comparison to the massive earth and concrete works. However, large pumps are required for the dam operation. It is also to be noted that an entire village had to be relocated in order to clear the necessary area for the reservoir. Construction activity due to the village relocation has not been considered in this study.

Total CO_2 emissions of over 182000 tonnes were derived. Dividing the emissions by the storage capacity of the dam and multiplying the figure by the entire dam capacity of the island yields in 514000 tonnes of CO_2. Consequently, the dam footprint becomes significant.

3.2 Desalination

The history of seawater desalination dates back to the 1950s when the only available technology was distillation [12]. In the 1960s the development of desalination technologies continued and concentrated around dual-purpose plants combining power and water production by nuclear reactors. By the 1970s two new technologies had emerged, namely multi-effect distillation (MED) and reverse osmosis (RO) [12]. At the moment, RO technology has the lowest specific energy consumption [13].

Frequent draughts and water shortages in the 1990s forced the Cyprus government to opt for desalination. Subsequently, the first desalination plant utilising the RO technology was commissioned in 1997 in Dhekelia with a capacity of 20000 m^3/day. The plant capacity was upgraded to 40000 m^3/day a year later [14]. Its guaranteed contracted energy consumption is 5.3 kWh/m^3. In 2001 a second desalination plant was commissioned with 54000 m^3/day capacity [15]. The Larnaca plant is operating at higher energy efficiency of 4.52 kWh/m^3. Both plants were implemented utilising BOOT contracts, i.e. the successful bidder had the responsibility to build, own, operate and eventually transfer the ownership to the Water Development Department of Cyprus. The contract dictates that the energy consumed per cubic metre of water does not exceed the agreed figures. If it happens, the contractor is expected to pay the difference. Similarly, the government of Cyprus is obliged to buy all the water produced over the ten years of operation before the ownership transfer.

The contract structure has not been without problems. First of all, it has been difficult to alter and improve the technology because the contract dictates that the hand-over of the plant must be as tendered. Commissioning of the Dhekelia plant revealed that the agreed energy consumption figures could not be achieved with the energy recovery systems (Francis turbine) in place [6]. The initial energy consumption was in excess of 6 kWh/m^3. Series of upgrades in the energy recovery systems, such as adding a pressure exchanger, were done over seven years in order to bring the plant to the contracted energy consumption. Secondly, the contractual fixed volume production rate does not give the opportunity for the water authorities to manage the supply efficiently. The client is obliged to buy the same amount of water during a drought as well as a rainy season whereas ideally the quantities should be adjusted according to demand.

Desalination has alleviated the immediate water shortages on the island and currently no water rationing is in place. However, the price of desalinated water is high both in monetary and environmental terms. The environmental impacts of desalination include issues related to land use, groundwater, marine environment, noise pollution and energy use [16]. Industrial appearance of desalination plants has a negative impact on the recreational use of the coastline. Groundwater level and quality could be affected by feed drilling or leakage in brine discharge pipeline. Marine life impacts are mainly felt at the brine discharge outlet where inadequate mixing of brine with seawater and added chemicals used in water pretreatment may cause a hostile environment for the sea ecosystem. The chemical composition of the brine includes residues of antiscalants, antifoulants, antifoaming agents and corrosion products, such as copper, nickel, chromium and zinc[2]. In addition, water intake structures can be dangerous especially for fish. Although drum screens with 5mm mesh are typically provided between intake structure and feed water pumps to prevent lager fish from entering, impingement of fish upon the screen and entrainment of biota in the feed water system does occur leading to descaling, physical damage and disorientation to fish, which in turn increase mortality due to disease and vulnerability to predation [17]. But the most profound environmental effects are associated with the energy consumption by the desalination process itself. In Cyprus one cubic metre of desalinated water consuming 5.3 kWh of electricity emits nearly 5 kg of CO_2 [3] [18], [19]. Dividing the total daily emissions due to both plants over the permanent population, the emissions

[2] In case of thermal plants. Corrosion is not significant for RO plants operating in ambient temperatures and utilising stainless steel metal parts.

[3] CO_2 equivalent of 0.93 (kg CO_2)/kWh for grid electricity calculated as per data given in Ref. [18] and [19]

become 200 kg/capita/yr and constitute ten percent of the 'one planet' emission target of 2000 kg/capita/yr. Needless to say that with such a portion taken up by water, one planet targets cannot be met. Therefore, the impacts of wider use of desalination have to be carefully evaluated in the context of the island's overall sustainability plan.

4 Water consumption and the tourism sector

Water consumption in hotels varies based on the level of service offered. For example, the presence of a swimming pool or spa will increase the overall water intensity. Similarly, laundry facilities can be in-house or contracted out and food serving facilities vary from continental breakfast bars to full service restaurants. The following section presents water consumption benchmark figures for different classes of hotels.

4.1 Benchmarks

Table 4.1 shows benchmarks for water consumption in Mediterranean hotels. For example, a 250-room luxury 5-star hotel may have daily water demands as high as 550 m^3 [4]. A comparison of water prices in four major tourist areas is shown on Table 4.2. The comparison clearly illustrates two things, namely the large regional differences in water prices and in general, the high price paid by hotels for potable water. In contrast, prices for 300 m^3 daily demand rating 'excellent' are shown also highlighting the financial savings potential.

Hotel Rating	Benchmarks (litres/guest night)			
	Excellent	Satisfactory	High	Excessive
Luxury fully serviced	<600	600-750	750-1100	>1100
Mid-range fully serviced	<450	450-600	600-950	>950
Small and budget fully serviced	<220	220-250	250-380	>380

Table 4.1 Water consumption benchmarks for Mediterranean hotels

(Source: benchmarkhotel.com quoted in: Sustainable hotel: siting, design and construction [20])

Tourist Area	Price in € for 550 m^3 of water (hotel tariff)	Price in € for 300 m^3 of water (hotel tariff)
	Excessive daily consumption	Excellent daily consumption
Limassol	171.65	93.74
Pafos	1117.59	598.23
Larnaca	701.89	318.61
Agia Napa	1203.99	650.00

Table 4.2 Water price comparison in four major tourist areas of Cyprus

(Source: respective water authorities)

It is also important to understand where water is consumed within a hotel. Figure 4.1 shows an indicative breakdown of water usage suggesting that guest rooms are the largest consumers, followed by the kitchen, locker rooms/public toilets and the laundry. Therefore, it appears that water saving measures should target these areas in the first place. Table 4.3 gives actual

[4] Assuming full occupancy and two people per room.

benchmark quantities for guest room, kitchen and laundry consumption. It is of particular interest to compare the guest room consumption of 220 litres to domestic per capita water consumption which in Cyprus is around 126 litres daily[5]. Therefore, it becomes obvious that even with best practise hotels still are large consumers of water and it seems unfair that the local population must bear the consequences of draughts while tourists have access to unlimited water supplies. It was this inequality in burden sharing that embarked the current study in the first place.

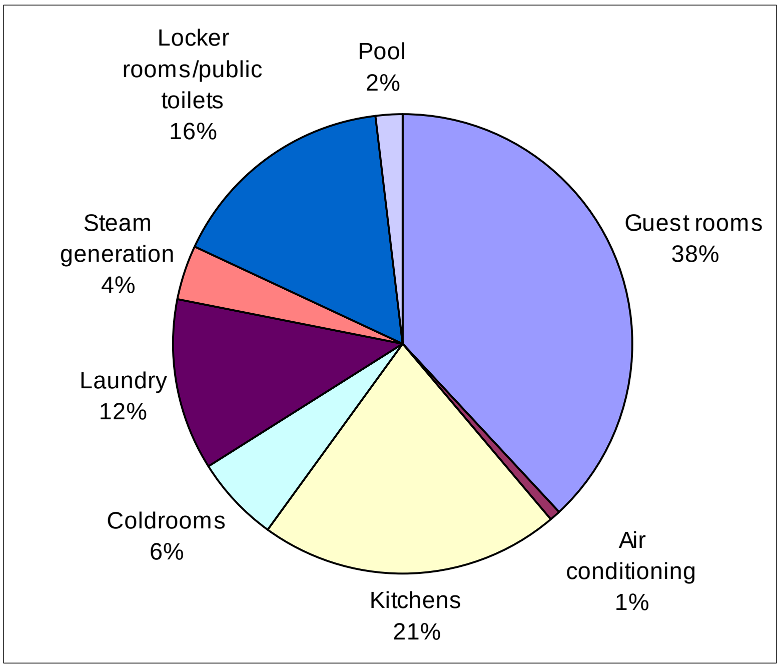

Figure 4.1 Indicative water use in hotels

(Source: Key Performance Indicators for water use in hotels. CIRIA W10 [21])

Department	Daily Consumption
Guest rooms	<220 litres/guest
Kitchens	<35 litres/cover
Laundry	<20 litres/kg

Table 4.3 Water benchmarks for daily individual consumption

(Source: International Tourism Partnership working group quoted in: Sustainable hotel: siting, design and construction [20])

4.2 Tourism industry and its leading role in water conservation

In the post-cheap-fossil-fuel-world the whole concept of 'travel for leisure' is questionable. The term 'sustainable tourism' is an oxymoron at its best since strictly speaking air travel can never be considered sustainable. However, it has become a human right to travel and explore

[5] Figure for Larnaca Water Board area for 2004. During supply restrictions in 2000, the figure was 105 l/d per capita.

and in this context it is increasingly important that the other negative impacts of tourism are minimised. Energy and water efficiency should take the front seat in such endeavours. Both passive and active resource saving measures should be implemented in hotels. In the context of water conservation, efficient fixtures and fittings represent passive measures that will not require any attitude change from the end user. Active means include measures such as giving the guests a choice for reusing towels or educating housekeeping staff in water conserving cleaning techniques. The psychological element of choice is equally important as efficient technologies because no permanent savings can be reached without willingness to change.

In Cyprus the hotel sector has a potential of building a green image by adopting small scale renewable energy powered desalination systems. The feasibility of such systems has been studied by Glekas et. al. [22] and the indication is that they can become economically viable provided the government sets up an appropriate grants programme. The study was done using water and energy prices prior to 2000. Therefore, the viability of such systems is likely to improve as the municipal water prices increase and desalination technologies improve in energy recovery.

5 The way forward

It is believed that desalination in Cyprus can only be a part of long term sustainable water management. Relatively low fossil fuel prices coupled with government subsidies in water pricing has made it possible so far to support desalination. However, the fuel prices are destined to rise further making it increasingly more difficult to desalinate cheaply. Any improvements in desalination technology are bound to be nullified by energy price increases. The only solution to sustain desalination appears to be using renewable energy sources in powering it. Although the technology exists, is successful elsewhere and a feasibility study in the Cypriot context indicates that small scale applications could be successfully implemented [22], Cyprus has yet to embrace it.

In any case, as concluded in a regional study on desalination in the Middle East, North Africa and Central Asia by the World Bank, ‘desalination alone cannot drive the promise of improved water supply’ [23]. If other cheaper and less benign water supply and conservation methods are not implemented in parallel or if a poor policy or management structure is in place, desalination is destined to lead to wasteful and inefficient expenditure of public money. Therefore, the following measures identified by Schiffler [23] should be considered before embarking on large scale desalination projects in order to ensure an overall efficient water management strategy:

a) reduction of non-revenue water;
b) appropriate cost recovery;
c) limited use of targeted subsidies;
d) sound investment planning;
e) integrated water resources management;
f) proper environmental impact assessment and
g) capacity building in desalination together with water resources and utility management.

5.1 Opportunities for water conservation

Water saving potential can be illustrated with the following simple example: assuming a population equivalent of 1M on the island (locals + tourists) each flushing a toilet four times daily (10 l per flush) equalling to 40000 m^3 of water per day. If all toilets were fitted with 2/4 litre dual flush mechanism, the per capita consumption could be reduced from 40 l to 10 l/day yielding daily savings of 30000 m^3 of water; 75 percent of the capacity of the Dhekelia desalination plant, and subsequent reduction in CO_2 emissions of nearly 150 tonnes. Similarly, closing the tap while brushing teeth could save 17600 m^3 of water per day and 87 tonnes of CO_2. The above two measures alone would cancel the need for one of the desalination plants.

Efficient shower heads can reduce the water flow rate from a typical 17-30 l/min to 9.5 l/min without any marked reduction in performance [24]. Thames Water in the UK recommends 5 l/min for hotel showers [25]. Therefore, improvements in toilet and shower efficiency are an ideal way especially for hotels to conserve water and typically they have a short payback period.

The simplest way of saving water is assuring that no leakage takes place. A leaky faucet that fills a coffee cup in 10 minutes will waste 12.4 m^3 of water a year [24].

A total annual amount of 7.3 Mm^3 can be collected from the domestic rooftops alone by harvesting rainwater[6]. With no or minimal treatment, stored rainwater can be used for irrigation and toilet flushing. Urban rainwater collection would be beneficial also in terms of flash flood control which is a persistent problem in densely built-up lowland areas due to the inherent inadequacy of the storm sewer network in place. Furthermore, instantaneous rainwater capture would appear desirable in a climate where evapotranspiration accounts for 86 percent annually [4].

5.2 Future policies

As shown above, simple technologies and attitude changes can result in large water savings. However, without appropriate awareness campaigns and policies including lucrative financial incentives, any voluntary large scale adoption is unlikely. The usual way of driving the market forces towards reduced consumption is to increase the price of a commodity but at the same time to give incentives for efficiency and independence. Therefore, any new water policies on the island should carefully balance the use of revenue from water sales. It is suggested to implement a water pricing structure that would increase the unit cost of water but at the same time make certain efficiency improvements mandatory so that the total price paid by the end users would stay at the current level or marginally increase, yet for a lot less quantity. The extra revenue thus collected could then be disseminated as grants for partial financing of the infrastructure improvements. Similarly, effective penalty clauses should be integrated into the price structure so that the 'polluter pays' principle were fully recognised. It is common practise in construction to impose minimum standards for seismic and thermal performance of buildings. There is no reason why similar standards for water efficiency could not be applied at the legislative level in a country where draughts are more frequent than earthquakes.

It is beyond the scope of this study to do a detailed economic analysis to evaluate the impact and sensitivity of the parameters discussed, but rather to propose the concept for further study.

6 Conclusions

Cyprus as a semi-arid island has a challenging task ahead to adapt and revise its water supply and policy strategy to harmonise with the EU Water Directive. It will require massive water conservation measures in the urban scale coupled with rethinking the supply-related issues, large scale use of fossil fuel powered desalination in particular. Furthermore, the tourism industry has a potential for significant savings at the same time sharing more equally the burden of conservation.

This study shows that even conventional water supplies, such as dams, carry a large ecological footprint. Therefore, the only truly sustainable solution is demand reduction. Water conservation measures should be fitted into a larger picture for a sustainable future of the island. Such efforts warrant interdisciplinary collaboration between the different stakeholders. Savings in CO_2 emissions go hand in hand with minimising the use of desalination as the Larnaca plant is among the five largest consumers of electricity on the island [15]. Therefore, any new capital investments in water infrastructure must be in sync with efforts to reduce the island's dependency on imported fossil fuel and related CO_2 emissions.

[6] Assuming 100 m^2 roof area for 270000 houses, 300 mm annual rainfall precipitation and 90% rainwater collection efficiency

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References:

1. Delft Hydraulics, E.S.A., D. Argyropoulos & associates (2006). *Total unit costs of domestic water supplied by the Government through the Government Water Works.* Report Q3629, Contract No. 39/03/61.

2. Water Development Department; Ministry of Agriculture, Natural Resources & Environment (2003). *Development of water resources in Cyprus: a historical review*. Press and Information Office, Republic of Cyprus.

3. Water Development Department; Ministry of Agriculture, Natural Resources & Environment (2001). *Dams of Cyprus*. Press and Information Office, Republic of Cyprus.

4. Water Development Department; Ministry of Agriculture, Natural Resources & Environment (2002). *Use and conservation of water in Cyprus*. Press and Information Office, Republic of Cyprus.

5. European Commission (2000). *Water Directive 2000/60/EC establishing a framework for Community action in the field of water policy.*

6. Villa Sallangos, O.L. (2005). *Operating experience of the Dhekelia seawater desalination plant using an innovative energy recovery system.* Desalination 173 (1), pp.91-102.

7. Bird, J. (2002). *Nine months after the launch of the World Commission on Dams report.* International journal of water resources development 18 (1), pp.111-126.

8. The World Commission on Dams (2000). *Dams and development: a new framework for decision-making*. Available at: http://www.dams.org//docs/report/wcdreport.pdf. (Accessed: 28-10-2006).

9. Victoria University of Wellington (no date). *Embodied energy coefficients*. Available at: http://www.vuw.ac.nz/cbpr/documents/pdfs/ee-coefficients.pdf (Accessed 25-10-2006).

10. Rubber Manufacturers' Association (2006). *Typical materials composition of a tire*. Available at: http://www.rma.org/scrap_tires/scrap_tire_markets/scrap_tire_characteristics/ (Accessed 1-11-2006).

11. Nunnally, S.W. (1987). *Construction methods and management.* 2nd ed. Englewood Cliffs, New Jersey, USA: Prentice-Hall

12. Glueckstern, P. (2004). *History of desalination cost estimation*. In: International Conference on Desalination Costing. Limassol, Cyprus: Middle East Desalination Research Center.

13. Wilf, M. (2004). *Fundamentals of RO-NF technology*. In: International Conference on Desalination Costing. Limassol, Cyprus: Middle East Desalination Research Center.

14. Siamarou Marangou, V. and Savvides, K. (2001). *First desalination plant in Cyprus – product water aggressivity and corrosion control.* Desalination 138 (1-3), pp.251-258.

15. Koutsakos, E., Savvides, K., and Savva, K. (2005). *Larnaca desalination plant operation - a client and contractor perspective.* Desalination 184 (1-3), pp.157-164.

16. Einan, R., Harussi, K., and Perry, D. (2002). *The footprint of the desalination processes on the environment.* Desalination 152, pp.141-154.

17. Loizides, L. (2004). *The cost of environmental and social sustainability of desalination*. In: International Conference on Desalination Costing. Limassol, Cyprus: Middle East Desalination Research Center.

18. Electricity Authority of Cyprus (2005). *Annual Report 2004*. Available at: http://www.eac.com.cy/EAC_Homepage.nsf/6b254d1af9888993c22571080032270b/$FILE/ANUAL%20REP.%20%20FOR%20WEB-ENG.pdf (Accessed 9-11-2006).

19. CIBSE (2004). *Energy efficiency in buildings, CIBSE Guide F*. 2nd ed. London.

20. International Tourism Partnership (2005). *Sustainable hotel: siting, design and construction*. Conservation International.

21. Waggett, R. and Arotsky, C. (2006). *Key Performance Indicators for Water use in hotels.* CIRIA W10. London.

22. Glekas, I.P. and Stylianopoulou, E. (2000). *Market prospects for RES-powered desalination systems in Cyprus*. In: RES-powered desalination systems in the Mediterranean region: from identification to project implementation. Limassol, Cyprus: European Commission Directorate General for Research.

23. Schiffler, M. (2004). *Perspectives and challenges for desalination in the 21st century.* Desalination 165, pp.1-9.

24. Alliance to save energy (2005). *Water Efficiency*. Available at: http://www.ase.org/section/topic/ee_hotels/hotel_water (Accessed 29-10-2006).

25. Thames Water (2006). *Water Efficiency in Hotels*. Available at: http://waterwise.fortune-cookie.com/business/hotels-index.asp (Accessed 31-10-2006).