4. URBAN WATER CONSERVATION

Traditionally, in the water supply and demand equation, the variable X has always been on the supply side that was solved simply by finding the amount of water matching customer's expectations. However, during the past 15 years, management strategies have experienced a significant shift: demand is now considered as a second variable instead of an imposed factor. Today California's water supply challenges are no longer analyzed as a first grade equation, but as a multivariable expression that requires engineers and policymakers to make constant iterations in order to find the optimal solution, both for customers and the environment. This combination of supply-and-demand management strategies is what water agencies define as integrated resource planning (IRP) (DWR Water Supply Update 2005)

Water conservation could be defined as reduced water use, without cutback in its derived benefits. Water conservation, also referred as water use efficiency, is mostly based on reduction of losses and unnecessary water uses. Therefore, two basics tools to increase water conservation are technical improvements (reservoir automation, leakage repair, etc) and public education. Moreover, water savings can be stimulated by a rise in the price. Increasing block rate structures and increased price during periods of peak demand have proved to be very efficient tools in terms of water savings. These strategies will not be discussed in this thesis though, due to their high level of complexity. In addition, water prices in California and Spain are difficult to compare because different agencies have very different billing systems and in many cases the price paid by user also includes sanitations costs.

Water use efficiency practices have multiple advantages, compared to increased water supply strategies (desalination, transfers, surface storage, etc). First, water use efficiency avoids the construction of new infrastructures, including pumping, conveyance, storage and treatment facilities (DWR, 2005). Moreover, decrease in water demand leads directly to significant energy savings linked to water supply. According to the California Energy Commission, water-related activities account for 19% of the State's power demand, one quarter of which is used in water supply and treatment (CEC, 2005). In addition, reduction in water use translates in reduced amounts of generated wastewater and therefore a drop in costs associated to sewer conveyance and treatment.

4.1. Urban Water Use in California and Spain

Urban water in California and Spain is mostly used as a supply for residential customers, while only a quarter of the total urban demand is used commercial, industrial or municipal proposes (Table 5).

Besides the similarities or differences regarding urban water uses, it is necessary to point out the importance of water losses in both countries. Spain looses almost one fifth of it urban water through leakage within the networks. Surprisingly, the Region of Valencia is number one in the rank of loses (25%) of all seventeen Autonomous Communities, although it is one of the most sensible regions to water supply and a leader of the platform in support of the Ebro transfer. In 2004, losses throughout the Region of Valencia, Andalusia and Murcia combined ramped up to 360 hm^3, which is as much as 35% of what the controversial transfer was supposed to provide.

Table 5. Urban water uses in California and Spain

Urban water use	California	Spain
Residential demand (liter/person/day)	614	164
Total use (hm^3/year)	10,857	4,002
Residential	62%	54%
Single family	46%	N/A
Multi family	16%	N/A
Commercial	12%	19%
Industrial	5%	
Landscaping	10%	-
Public use*	-	6%
Other	1%	2%
Losses	10%	18%
The INE refers to public use as "municipal use" which includes uses such as street cleaning, public fountains, etc		

Sources: DWR (2003), INE (2005)

In contrast, California water losses vary between 7% and 15%, assuming a 10% as a good average (personal communication with DWR). However, there are several systems with the California foothills that have system losses in excess of 20%. DWR is not going to fix those systems since water losses serve as supply for the flora and fauna in these areas. Only by reducing loses to those of California, in 2004 Spain would have saved almost 500 hm^3, which is equivalent to 1,5 times the amount of desalted water produced in that same year. However, it should be noted that the high level of losses in Spain could be partly explained by the old age of the Spanish networks compared to those of California.

In California the average residential customer uses over 614 liters/day (data from the DWR, 2005), whereas Spaniards use 3.6 times less water, only 164 liters/day (INE, 2004). The main reason for such a dramatic difference between both regions lies in private landscape irrigation. Residential buildings in California are mostly single-family houses or small condos with no more than three stories, generally provided with their own front and/or backyard. This urbanization pattern is found throughout the entire state, including densely populated cities such as San Francisco. In contrast, Spanish urban areas consist basically of tall apartment buildings with no private gardens, which obliviously cuts down dramatically the water demand for outdoor uses.

Californian residential customers use 70% of their water outdoors, whereas only a small portion is used indoors (DWR, 2003). Actually, residential water indoor use in California is 176 liters/person/day, which is very close to Spain's 164 liters/person/day.

Analyzing data on a larger scale, including large landscaping (institutional facilities, public parks, etc) it comes to light that over half of total California's urban water supply is dedicated to irrigation of public and private landscapes (see Table 6). It should be pointed out that many of these irrigated urban areas are grown in arid or semi-arid areas of the Central and Southern California and that state-wide urban water demand could be easily reduced by substituting current landscaping species by native and less water consuming types of plants.

It is worth pointing out that while indoor demand remains relatively constant throughout the year, outdoor water use ramps up in summer when demand for irrigation increases. In fact it is during dry and hot years when landscapes need more irrigation water, but also it is during these periods when water supply tends to be more scarce due to lack of precipitation and snowpack.

Table 6. Indoor and Outdoor water use in California

Urban water use (hm^3) 2003	Total		Indoor		Outdoor	
Single Family Residential	51%	5303	28%	1498	72%	3805
Multi-Family Residential	17%	1802	30%	543	70%	1260
Commercial	13%	1393	100%	1393	0%	0
Industrial	6%	601	100%	601	0%	0
Large Landscaping	11%	1169	0%	0	100%	1169
Total		10475	39%	4034	61%	6233

Data from DWR, 2003

Besides residential water demand, California's industrial and commercial water use is also much higher than that of Spain, yet both regions generate similar gross (domestic or state) product. While agriculture only contributes with a small percentage of total GDP (or GSP), commercial and industrial activities generate most of the region's wealth. For every cubic meter California's commercial and industrial customers use, the State generates $838/m^3 resulting from these activities. Spain's "economic productivity" is almost twice as high, $1,504 per cubic meter.

4.2. Urban Water Conservation in California

California went through one of its most severe droughts between 1987-1992. Despite its terrible environmental consequences, lack of water tough Californians very valuable lesson on water use efficiency. Today almost every water agency has educational programs including on/line tutorials and also active teaching in schools. DWR provides user-friendly guides to efficient water use, specially targeting residential irrigation. A number of publications such as Model Water Efficient Landscape Ordinance, Water Use Classification of Landscape Plants (WUCOLS) and Graywater Guide are available on-line together with Public Affairs Office's Water Education Program. The Metropolitan Water District of Southern California is one of the best examples of agencies aiming towards public awareness about water use efficiency. Besides proving an extensive range of information on the web site www.bewaterwise.com, being a large agency, MWD is able to host and fund free landscaping training classes, both on-line and active presence.

From an institutional point of view California has carried out a large effort creating and funding several offices and agencies, from state to local level, working specifically on water conservation issues. The Office of Water Use Efficiency and Transfers assists DWR about urban and agricultural water conservation and energy efficient water use (including transfers). Among other activities, the OWUE provides loans and grants and also local assistance to customers and agencies, and manages the California Irrigation Management Information System (CIMIS), which will be discussed further on. DWR is the only institution that deals with urban and agricultural water conservation in a large scale, whereas the rest of water conservation agencies and programs are usually focused on one use.

How much water will California require in the future is still uncertain, but what is for sure is that demand will continue to increase. DWR within its 2005 Water Plan framework and Public Advisory Committee developed projections studies in order to estimate water uses by 2030 horizon under three possible different scenarios (Table 7). The first one is based on current population, industrial and water use trends, the second one assumes higher water use efficiency and environmental whereas the third (less resource intensive), and last one, foresees an increase in growth and water demand rate without additional water conservation (more

resource intensive). Extensive information about DWR forecast methodology and their IWR-MAIN Water Demand Analysis Software is publicly available on their web site.

Table 7. Future water demand

Scenarios	Net Changes (hm^3/year)	Increase referred to 2001 use	Total 2030 (hm^3/year)
Current Trends	3,701	35%	14,309
Less Resource Intensive	1,645	16%	12,253
More Resource Intensive	7,237	68%	17,845

Source: DWR 2005

The California Bay-Delta Authority (CBDA) carried out a study estimating urban water use saving by the year 2030 under six case scenario, each of them assuming different levels of public funding (DWR, 2005). Projection 6 represents the technical potential of the urban conservation measures evaluated by CBDA. It assumes 100% adoption statewide of these measures using existing technologies and provides a reference point for the other five projection levels. The results proved that the more money would in conservation, the greater the water savings. As a result of water savings programs, urban water demand in 2030 could be 10 to 27 percent lower than it would be without any conservation measures (Table 8).

Table 8 . Water use changes for different projection levels

Projection levels	Assumed Local Agency Investment	Annual State investment ($ Million)	Water use changes referred to 2030 demand following current trend
1	Historic Rate	99	-10%
2	All Locally cost-effective[1]	192	-16%
3	Historic Rate	143	-12%
4	All Locally cost-effective[1]	236	-18%
5	All Locally cost-effective[1]	236	-18%
6[2]	N/A	N/A	-27%

[1]Benefits from local water savings are larger than the projects cost

[2]Projection 6 represents the technical potential of the urban conservation measures evaluated by CBDA. It assumes 100% adoption statewide of these measures using existing technologies and provides a reference point for the other five projection levels

Source: DWR 2005

The CBDA's study estimates a notorious increase in demand for the next 30 years: between 11% and 21% of 2001 water use. These projections have been contested by report conducted by The Pacific Institute (PI) report, California water 2030: An efficient Future (2005). The Pacific Institute maintains that by implementing the appropriate conservation measures urban water use in 2030 could drop by 10,361 hm^3/year, which is 6% lower than it was in 2000. However, these results overestimate potential water savings for two reasons. First, Pacific Institute's calculations are based on data published in DWR California Water Plan Update 2005 that includes not only raw water use but also second uses of wastewater (water reuse or reclamation). However the Pacific Institute's projections only take into account raw water

demand and therefore are significantly lower compared to total water use in 2000, which included water reuse. In other words, difference in water use estimated by the PI is not only due to conservation measures but also to the fact that water reuse volumes are not taken into account. Furthermore, Pacific Institute claims non-price-driven efficiency is the key to future water conservation but no precise programs have been described nor has any cost-benefit analysis been conducted. Therefore, I believe that Pacific Institute's forecast is, in some way, unrealistic.

Future savings due to conservation measures and their costs are certainly difficult to evaluate as they vary widely depending on local funding, possible changes in water use, water availability, etc. However, for every funding level CBDA estimates a statewide average unit cost (Table 9) that range from \$0.184 to \$0.423 per m^3. It should be noted that potential water savings for projections 1 to 5 are 40 to 70 percent lower than the technical potential. In fact, DWR estimates that achieving the technical potential savings would not be economically profitable because of diminishing returns on investment.

Table 9. Potential savings and their costs

Projection levels	Average Unit cost of Water Savings (\$/m^3)	Potential water savings (hm^3/year)
1	0,423	1,422
2	0,181	2,297
3	0,320	1,726
4	0,184	2,600
5	0,189	2,560

Source DWR 2005

From data shown in Table 9, it is clear that the larger the potential water savings the more cost-effective are the conservation measures. Potential water savings are directly correlated to the amount of public funding and therefore marginal cost of water savings also decrease with expenditure in conservation program (Figure 4). For projection levels 1 to 3, every additional dollar invested in water use efficiency entails a drop in unit cost of \$0.0026/m^3. Yet for higher funding levels, unit cost remains unchanged. Although In some cases large investments may not correspond to the financial optimal, they may be justified due to significant environmental benefits.

Although water-use efficiency programs are still too expensive to be implemented at their full potential extent, conservation remains one of the most cost-effective ways of solving the supply-demand equation. Actually, water supply alternatives are still between two and four times more expensive. Cost of recycled water in California ranges from \$0.276 to \$0.477 per m^3 (West Basin Municipal Water District, Orange County Water District) while desalted seawater is obtained at a cost of \$0.649 to \$1.621 per m^3 (DWR, 2005).

However, conservation also has some important drawbacks. Unlike desalination, water use efficiency programs do not provide a new "ready-to-use" source of water. Instead, water savings are achieved as a result of the combination of a large variety of actions that require continuous efforts not only from water agencies but from final water users too. All participating agencies must coordinate their different programs when targeting the same group of customers. In addition, they must make sure information is made easily available to the

users. Once water conservation measures have been implemented, agencies should verify that newly introduced programs continue to be run efficiently.

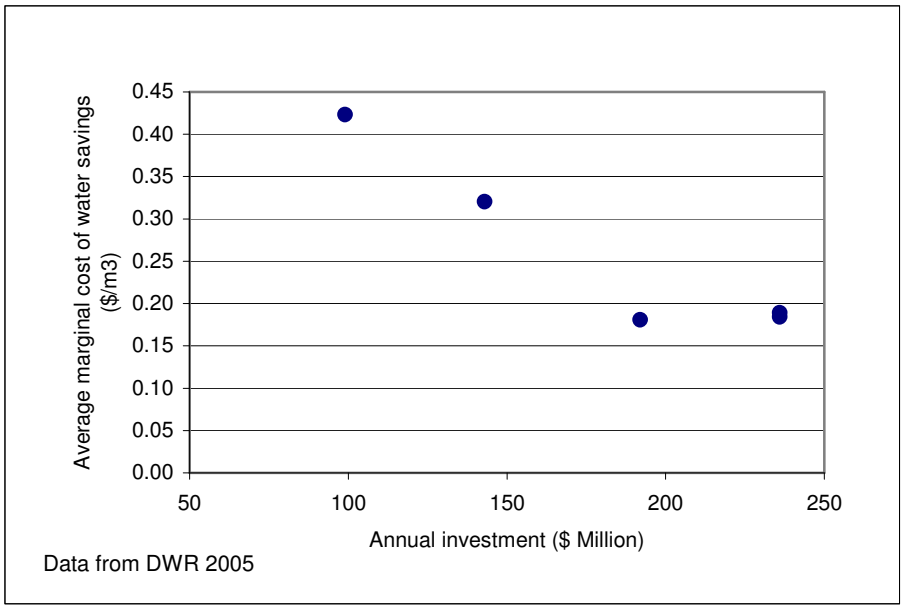


Figure 4. Marginal cost of water savings

4.2.1. California Urban Water Conservation Council

In order to orchestrate the number of stakeholders and conservation programs existing state wide, in 1991 one hundred water agencies decided to join their forces and created the California Urban Water Conservation Council (CUWCC), a non-profit organization who aims to increase water use efficiency by implementing a series of water conservation measures known as Best Management Practices (BMP's). Today the Council has 384 members belonging to three different groups: water suppliers, public advocacy organization and other interest groups. All members of the council become signatories of the Memorandum of Understanding (MOU) by which they commit to develop and implement every BMP that is cost-effective, meaning that the cost per m^3 of putting in place the BMP is less than the cost of acquiring new water (Totten, G. 2002). The CUWCC has created a guide describing cost-effectiveness as well as a spreadsheet that calculates cost and benefits of BMP's. Besides paying for their own locally cost-effective projects, agencies can apply for public state or federal funds.

In 2006, CUWCC spent over $2 Million in water conservation programs, including statewide implementation programs, other special projects research and standards and technical assistance among other activities. The Council's projects are mostly financed with public grants, which in 2006 were up to $1.7 Million. Financial support comes from both state and federal sources including public voted DWR Proposition 50 Water Use Efficiency Grant, California Public Utilities Commission water and energy savings Grant, Alliance for Water Efficiency (AWE) and US Bureau of Reclamation. The council's members represent its second major source of revenue. In 2006 all the members' dues combined added $789,556 (CUWCC, 2006)

The CUWCC's BMP Cost & Savings Study (2005) includes a complete list of all 14 BMP as well as the requirements that should be followed to guarantee the correct implementation of

the cited practices. Table 10 summarizes CUWCC's 14 BMP and water savings obtained through each of them since 1991 when they were first implemented (CUWCC, 2007).

Table 10. Savings achieved through BMP's

Best Management Practice (BMP)	Gross Water Savings (hm^3)
1. Water Survey Programs for Single-family and multi-family residential customers	109
2. Residential Plumbing Retrofit	105
3. System Water Audits, Leak Detection and Repair	N/A
4. Metering with Commodity Rates for all New Connections and Retrofit of Existing	44
5. Large Landscape Conservation Programs and Incentives	420
6. High-Efficiency Washing Machine Rebate Programs	17
7. Public Information Programs	N/A
8. School Education Programs	N/A
9. Conservation Programs for CII Accounts	408
9a. CII ULFT Water Savings	16
10. Wholesale Agency Assistance Programs	N/A
11. Conservation Pricing	N/A
12. Conservation Coordinator	N/A
13. Water Waste Prohibition	N/A
14. Residential ULFT Replacement Programs	1,136
TOTAL:	2,255

Source: California Urban Water Conservation Council. BMP Water Savings Summary Report

Total BMP's water savings are over two thousand million cubic meters, which is enough water to cover the City of LA's needs for almost three years. However, it should be noticed that BMP's total water savings since 1991 are in the same order of magnitude than DWR's annual water savings estimates for the future (1.4 and 2.6 thousand hm^3/year). This means that from today to 2030 DWR expects to save every year on average as much as all of the urban water the State has been able to conserve over the past 16 years.

It is to notice that half of the total savings have been achieved through water-use efficient toilets retrofit programs. In fact, toilets are the higher water-using devices within households. US Environmental Protection Agency estimates that toilets may use up to 26% of total domestic water and 40% of indoor water use (www.epa.gov). Throughout all of California, replacement programs have introduced over 2 million efficient toilets. Although this represented huge savings in the past, some experts argue that today there is very little potential savings left and that future conservations programs should start looking in other directions, especially efficient landscapes and irrigation devices.

4.3. Metropolitan Water District's Urban Water Conservation Programs

In order to look at California's urban water conservation programs, this paper will develop a case study focused on Southern California. In terms of hydrology, the densely populated area between the City of San Buenaventura (usually referred to as Ventura) and the Mexican boarder encompasses to the South Coast Hydrologic Region (SCHR). Despite covering only 7 percent of the state's surface, 28.335 km^2 (DWR, 2005), the South Coast Hydrologic Region has 19.3 millions inhabitants or 54 percent of the State's total population (DWR, 2003). This

region is even more densely populated than Catalonia would be if the entire population of Andalusia and Madrid moved to the Catalan region (data from the INE 2006). Almost half of California's total urban water use (47%) occurs in the SCHR.

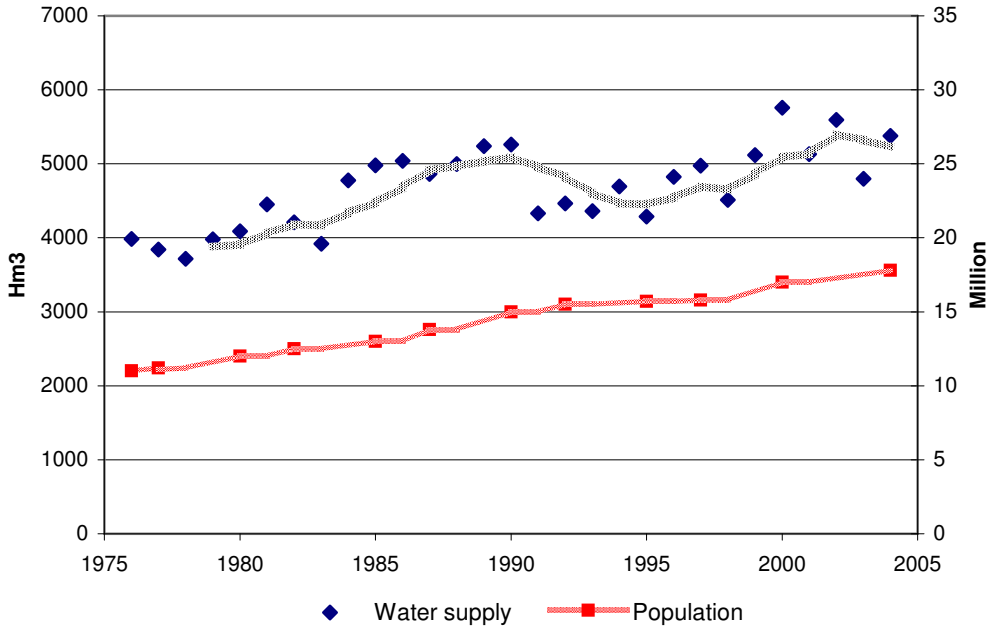
The main water supplier for the South Coast Hydrologic Region is the Metropolitan Water District of Southern California (MWD) who provides 73% of total urban water use for more than 18 million people over 47% of the SCHR area. MWD gets its water from four different sources: the State Water Project (41%), local supplies (38%), the Colorado River Aqueduct (16%) and the LA aqueduct (5%). MWD is a wholesaler, which means it does not deliver water directly to customers, but instead it sells it to retailers. MWD has retail contracts with 26 agencies that may either supply their users or resell water to other smaller agencies. These cities and small agencies also receive water from local sources, recycling or desalination facilities. As a result, it is a blend of local and imported water that is delivered to the final customers.

When it comes to urban water conservation, MWD carries out a number of water-use efficiency programs that may eventually overlap with local agencies' water activities. Therefore, water savings result from a combination of actions coming from several stakeholders including retailers, local agencies, cities, customers associations, and ultimately individuals as water users. Analyzing water demand and water-use efficiency within the entire MWD region may lead to vague conclusions because of averaging very different situations. Indeed, some areas have made fairly no improvement regarding water conservation, whereas other cities such as Los Angeles provide strongly encourage conservation through additional funding. Actually, current water demand within Los Angels Department of Water and Power Service Area (LADWP) is 11% lower than it was in 1989 before the drought imposed restriction of water supply. During the same period if time, population in the City of Los Angeles has increased by 18%.

4.3.1. Water demand trends within the MWD service area

Within the MWD's service area water supply and population have grown significantly within the past 30 years, as shown in Figure 5. However, because of water shortage due to the 1987-1992 drought, MWD applied aggressive conservation measures that achieved a 10% drop in water use between 1991 and 1995 compared to the previous five years (1986-1990). This sudden drop in urban water use shows that demand within MWD's service area has indeed a certain degree of elastically and thus can be effectively called on conservation during dry periods. It is worth pointing out that drought also caused an impact on population growth. In fact, during the last dry years and until the late 1990's the population growth was virtually zero. Despite the drought's negative consequences, Californians gained a valuable experience in water use efficiency. Today water per capita water use within the MWD's service area is still at the same level it was immediately after the drought, around 727 liters/person/day (MWD 2005).

Even though the drought had significant effects on water use and population growth, it was three years after the 1987-92 dry period began than such impacts became obvious. Such a delay in people's reaction is party explained by the fact that it takes a certain amount of time to determine whether there is indeed a drought or if it is simply one random short dry period. In addition, once water entities including agencies or public institutions have decided to initiate mandatory conservation, it usually takes some extra time for measure to be implemented and result to be obtained.



Source: MWD's Regional Urban Water Management Plan, 2005

Figure 5. MWD service area water supply and population growth

4.3.2. MWD conservation programs

MWD conservation programs follow two main guidelines: the CUWCC BMP's and the 2004 Integrated Water Resources Plan (IRP). The purpose of the IRP is to establish regional targets for the development of water resources including conservation, local supplies, State Water Project supplies, Colorado River Aqueduct supplies and water drawn from regional storage and purchased though water transfers (MWD, 2004). The IRP is a result of the joined efforts of several groups including MWD staff, member agencies, member sub-agencies, groundwater basin managers and representatives from environmental, agricultural business and civil communities.

MWD differentiates two ways of water savings: "code-based" and "active". "Code-based" savings result from demand reductions driven by increase in the price of water and conservation-oriented rate structures as well as water efficient pluming codes. California 1992 Plumbing Code obliges new constructors to install water efficient devices like toilets (6 liters/flush), showerheads (9.5 liters/minute), urinals (3.8 liters/flush) and faucets in any building of new construction (MWD 2005).

Although conservation ordinance intend to achieve water savings, experience tells us that, in the worst-case scenario, they could also lead to increases in water use if conservation measure are not correctly implemented. Such thing occurred in California in the 1980's when the first low flow toilets appeared. In 1980 a regulation requiring 13.25 liters/flush toilets in new constructions was approved before manufacturers were ready to build and users were willing to use the new devices. As a result of an early product launch, new low flow toilets were introduced in the market without having achieved the required technical quality and thus were unable to perform properly with low volume discharges Hence, users should flush their toilets at least twice before getting the same result they did with their old "high water use" toilets. As a consequence, unsatisfied low flow toilets users opposed to innovative toilets and eventually

to any conservation-oriented devices in general (personal communication with Chris Dundon, Water Conservation Supervisor for Contra Costa Water District. 05/30/2007).

Unlike "code based" savings, "active" conservation is achieved through Metropolitan and agency-funded programs, typically retrofits, installations and education within the MOU framework. Since MWD first implemented water conservation programs in 1990, over $177 millions have been invested and one thousand of hm^3 have been saved in residential, landscape and commercial uses. That is almost half of all BMP's statewide water savings since 1991. Currently, MWD budgets between $10 and $15 millions for water conservation programs, which are collected via the property tax. In addition, the Metropolitan regularly receives public grants from different sources: CALFED, Proposition 13, California Public Utilities Commission (CPUC), US Bureau of Reclamation (USBR), Water for the West and Proposition 50.

Over the past few years, water conservation within the MWD service area has increased progressively up to 2.6% in average of total urban water supply in FY 2003/04 (MWD 2005). On closer approach, water savings for landscaping represented 3.5% of total applied water for large-scale irrigation, while conservation within the residential sector was equivalent to 3.0% of total household water demand. In contrast, commercial water savings only totaled 0.3% of the demand for such use. In other words, commercial potential savings are ten times smaller than residential and landscaping.

Program expenditure and water savings decreased in fiscal year 2004/2005 primarily due to saturation of residential ultra-low flow toilets and reduction in commercial high-efficiency clothes washers incentives. MWD's conservation programs cover residential, industrial and landscaping water uses, although the residential sector benefits from over 90 percent of total water savings and funding, as shown in Table 11.

There are two fundamental points to be highlighted from the data shown in Table 11. First, the average investment per unit of water savings in landscape is by far the lowest amongst the three kinds of uses. For every dollar spent in landscaping water conservation MWD saves 15 m^3, while only 6 m^3 and 4 m^3 of savings are achieved respectively with residential and commercial programs. Therefore, we reach the conclusion that landscaping is 2.6 to 3.7 times more cost-effective than residential and commercial (lower investment per unit of savings). This mainly is due to the fact that certain water use efficient devices for irrigation such as new generation nozzles are very cheap to produce and install compared to low-flow toilets and high efficient clothes washers. Large landscaping water use in the South Coast hydrologic region accounts for 9% of total urban water use and is the second highest proportion in all California (DWR, 2005).

Second, MWD average cost-effectiveness over the past 15 years is 2.4 times higher that the historical state rate shown in Table 9, Projection level 1. MWD's average investment per unit of savings ($0.173/$m^3$) is even lower than the most optimistic of the five projections made by the DWR ($0.19/$m^3$). In addition, investment per unit of water savings in the past two years has been half of the historical average.

With the framework of water conservation, the MWD leads basically two kinds of programs: a) Direct conservation and b) Innovation programs

Table 11. Urban water savings and investment carried out by MWD

	Residential	Landscaping	Commercial	Total
Water Savings (hm^3)				
FY 2005/06	N/A	N/A	N/A	143
FY 2004/05	118	3	17	139
FY 2003/04	111	3	11	126
FY 2002/03	105	3	6	114
Since Inception (1990)*	937	33	50	1.163
Payments ($ millions)				
FY 2005/06	N/A	N/A	N/A	10.6
FY 2004/05	8.6	0.2	1.9	10.7
FY 2003/04	12.5	0.4	3.8	16.7
FY 2002/03	12.1	0.1	2.7	14.9
Since Inception (1990)*	162.3	2.2	12.2	187.3
Average investment per unit of water savings ($/$m^3$)				
FY 2005/06	N/A	N/A	N/A	0.074
FY 2004/05	0,073	0,064	0,110	0,077
FY 2003/04	0,112	0,120	0,333	0,132
FY 2002/03	0,116	0,032	0,457	0,131
Since Inception (1990)*	0,173	0,066	0,246	0,173

*Accumulative savings and payments for differentiated water uses between 1990 and FY 2004/05. Total savings and payments include FY 2005/06 achievements.

Source: MWD The Regional Urban Water Management Plan. February 2007

a) Direct conservation

Direct conservation consists of partnerships with the member agencies to install more efficient devices for residential, landscaping or commercial, industrial and institutional water use

a.1. Residential programs

Residential water-savings programs result from a joined funding effort coming from the Metropolitan and the water agencies by which customers receive substantial rebates for retrofitting their old inefficient devices for Ultra-Low-Flush Toilets (ULFTs), High-Efficiency Toilets (HETs) and High-Efficiency Clothes Washers (HECWs). Within the MWD's service area, residential customers use 52% of the water supply (37% SFR and 15%MFR).

Retrofitting existing devices is still a volunteer practice. However, cities of Los Angeles, San Diego and Santa Monica have made one step forward by passing a retrofit-on-resale ordinance that requires that all non-saving toilets and showerheads be replaced with water efficient models when a property is sold. Hence, the MWD's residential rebates programs are the perfect example of a combined "active" and "code-based" conservation program.

High-Efficiency Toilets – HETs

The MWD program is based on the pay-as-you-go formula, which means they will provide their member agencies with financial incentives for every new device in the area, but only once it has been correctly installed and is properly working. Rebates for are calculated on the basis of the amount of water each new device is able to save and not depending on the cost of

the product itself. This is the reason why the most important incentives are given for HET (up to $165/unit), which only use between 3.8 liters and 4.8 liters per flush. Prior to HETs, over 2,5 million ULFT (6.0 liter/flush) had been installed between 1988 and 2004 having an estimated lifetime savings (20 years) of more than two thousand hm^3.

Annual savings for HET and ULFT are, 62 thousand liters/year for the former and 42 thousand liters for the latter, which would translate into 57$/year and 39$/year for a single family in city of LA (data from MWD, 2005 and LADWP 2007). Customers often ask themselves is these kind of innovative water-saving devices are worth their higher price. The answer should always be yes, but the pay-off times vary widely depending on the applicable water rate, the rebates received and the price of the purchased toilet. Market price for an ULFT ranges from $60 to $200 and for a HET from $200 to $1000 (MWD). In the best-case scenario, users purchasing the cheapest toilets and benefiting from a high rebate may recover their investment in one year, yet upscale pressure-assisted models may need up to 15 years to become worth the initial investment.

High-Efficiency Clothes Washers – HECW

Clothes washers are estimated to be the second most important water user within a household accounting for 25% of indoor water use (American Water Works Association Research Foundation, 1999). In 1995, Metropolitan launched a clothes washer retrofit program which, up to today's date, has replaced more than 175,000 residential devices. During a 14-month period (2005 and beginning of 2006) the MWD provided its water agencies with a $2.5 million grant incentive for 33,000 new HECWs purchases ($75/unit rebate). Like toilets, HECW are also required to meet certain savings standards to be included in MWD retrofit programs. Clothes washer's efficiency is measured with the Water Factor (WF), which is the ratio of the amount of water used per washer capacity. In July 2005, it the Metropolitan set the acceptable WF to 0,8 or less. This same standard is set to go into effect statewide in 2010.

HECW use 35 to 50% less water and 50% less the energy than traditional top-loading washers. Their prices range from $600 to $1,500, which is about $200 to $600 more expensive than a conventional model. Again, pay-off time depends on a number of factors, but it is estimated that the purchase expense is recovered in about three years.

a.2. Residential Landscaping

Metropolitan funds a series of landscape surveys giving customers advise about how to improve their irrigation systems and picking the most suitable plants for their lawns. The California Friendly Home Program offers assistance and financial incentives for single-family and multi-family builders to incorporate California climate friendly species, high efficient nozzles and "smart" irrigation controllers, also named Residential Weather-Based Irrigation Controllers (WBIC). A WBIC adjusts its watering schedules based on local instant weather conditions (rain, temperature, sunlight, etc.) and is estimated to save an average of more than 50 thousand liters/year during its 10 years lifetime. Considering total urban demand of 812 liter/person/day within MWD service area (MWD, 2005), a 52% of residential use, of which 60% is outdoors a household with 3.5 people uses 334 m^3/year in landscape irrigation. By simply installing one WBIC the average household would save 15% of its outdoor water use.

Moreover, the California Friendly home program provides rebates for efficient rotating nozzles ($4/unit) and for "smart" irrigation controllers up to $80/unit for SFR and $1557/ha for MFR.

a.3. Commercial, Industrial and Institutional programs (CII)

The pursuit of water-savings in the business sector started in the1990s when Metropolitan carried out over 900 CII surveys in order to determine which conservation measures should be implemented and what would their cost be. In1999, the MWD partnered with its member agencies to conduct a three-year pilot project named the Regionwide CII Program. A vendor was hired to establish a toll free number as a single point of contact for the public and to manage all regional inquiries, request for applications, rebate processing, installation verification and marketing (MWD, 2006). Based on the success of the pilot project, in 2004, Metropolitan launched entered into a five-year, $20 million contract to provide continuity to the Regionwide CII Program. Since inception of the pilot project, the MWD has given incentives to retrofit over 80,000 devices saving 50 hm^3.

One of the keys to the success of the CII program is the fact that management of requests and funds is centralized and covers the entire MWD region, unlike the residential programs where every local agency handles rebates within its own area. This regionally administrated system makes it easier and more efficient for large industrial and commercial customers having business all over the area to join water-savings plans. Let's take, for example, the case of a large hotel chain. In the past, every hotel had to apply for its own conservation program and address its inquiry to its local agency, which lead to dozens of different inquires for the same company. The consequent bureaucracy made it slow and expensive to implement the programs. However, since the system was unified, any company within the MWD service area may submit one single application regrouping all its divisions. One additional advantage is the fact that, when business customers request retrofits for a large number of units, manufactures are able to offer lower prices and installations costs.

Besides rebates for retrofits and installations, Metropolitan drives the Industrial Process Improvement Program, which provides financial incentives on a pay-for-performance basis for improving water efficiency in industrial processes.

It is important to note that while dealing with commercial and industrial water users, sometimes savings on water bills in not enough reason for them to adopt water-saving measures. Actually, what these customers are looking for when making an investment is, not only making a financial profit, but also improving the business itself by making it more efficient. This is the reason why high efficiency toilets, for instance, may not seem very appealing for a businessman. On the other hand, devices such as the waterbroom do have and additional benefit for the business, as, a part from using less water (between 3 and 6 times less than a regular hose), it makes sweeping easier (75% less labor is required) and dries the floor faster. This is another good example of how California implements its conservation plans, not by the force of the law driven by the dictatorship of decision makers, but instead sweetening its programs using its well developed marketing tools.

Landscaping

As it happens in private landscaping, efficient irrigation systems are one of the keys to cut down water use in large non-residential lawns. In order to improve customer's access to WBIC, the Region-wide Commercial, Industrial and Institutional Program vendor now is in charge of the marketing and supply of "smart" irrigation controllers.

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Moreover, since 2004 the MWD runs a large landscape program that give member agencies the possibility of choosing among three different water-savings strategies. First, Water Use Accountability provides efficient irrigation water budgets and assists customers to achieve potential savings. Incentives are $6.2/ha/month if Metropolitan provides the training and $8.6 if the agency does. Secondly, Measured Water Savings incentives are provided based on accomplishments made by WBIC. For every thousand m^3 of verified savings, Metropolitan offers $93 and up to $125 are available when the agency provides the training. Finally, direct rebates are available for commercial and institutional customers to purchase WBIC benefiting from $1236/ha. In addition, technical guidance and training classes are offered for free via Professional Protector del Agua (PPDA) sponsored by the Metropolitan and the participating water agencies.

b) Innovation programs

Innovation programs provide funding for the pursuit of new ideas and development of innovative technologies.

Often manufacturers and individuals come up with innovative water-savings ideas. However, these new devices need substantial funding to be tested and eventually, brought to a larger scale. Metropolitan and the US Bureau of reclamation sponsor the Innovative Conservation Program, which every two years provides $500,000 in grants for the review of proposals and funding of the selected projects. In the best of the cases, funded pilot projects will bring successful results and will further be included in state-wide conservation programs. Actually, this is what has happened with the waterbroom and the X-ray film processing water recyclers, after they were developed by a ICP grant in 2001.

In addition, the Innovative Supply Program was created to review the number of proposals received by Metropolitan regarding new sources of supply. In 2004, 10 projects were selected among which there were an improvement for a storm water groundwater replenishment system and new approaches for recycled water using on-site, localized treatment..

4.4. Urban Water Conservation in Spain

Unlike California, Spain has no public organization in charge of the design and implementation of urban water conservation measures. However, the Ministry of Environment (MMA) together with the Ministry of Agriculture, Fishery and Food have recently created the National Drought Observatory (ONS) that will gather all departments and government bodies related to water management in order to built a centralized source of information that will help to improve nationwide drought mitigation projects. Eventually the ONS could include water conservation programs, although today is not one of its first priorities.

As far as local water agencies goes, none of the largest five Spanish cities has any urban water conservation plan similar to those existing in Los Angeles, San Diego or San Francisco. Even though large cities like Madrid and Barcelona post some information about water scarcity and savings recommendations on their websites, there is no sign of any rebate or personal educational program. In order to find out more about municipal water conservation initiatives, during the development of this research project water agencies of Madrid, Barcelona, Valencia, Seville, Zaragoza, Alicante and Murcia were directly contacted. Only Barcelona and Valencia water agencies answered providing some information about their educational campaigns but none of them happens to carry out aggressive conservation measures as Californian water agencies do. City of Valencia water agency, EMIVASA, has developed a drought mitigation plans that includes measures to be implement before a drought is declared

(loss reduction and quality improvement) and during the drought period (education, restrictions and changes in water rates).

4.4.1. Seville and Murcia, two examples of urban water conservation initiatives

Although in Spain there is no current retrofitting or education program comparable to those of California, it has been found that certain regions like Seville and Murcia are indeed moving in that direction.

Seville Water Agency (EMASESA) includes on its website very useful and accurate information about low flow devices (faucets and toilets). Despite the lack of rebates, EMASESA encourages its customers to purchase water efficient devices by providing detailed information on potential savings as well as a comprehensive list of stores where this kind of devices are available.

In July 2006 the Murcia Autonomous Community passed 10946 Law about increased savings and conservation measures for water consumption. The Law highlights the threat of a drought and the consequent need for water savings throughout the Region. Like the California 1992 Plumbing Code, Article 2 of 10946 Law states that suitable water conservation devices must be installed in all newly constructed homes in order to achieve the maximal level of possible water savings. Also, large modifications or integral repairs in existing buildings are subject to the same requirements as new constructions, which are specified in Article 2. In addition, volunteer water savings projects may qualify for a 10% reduction on the consumption conditions on the water bill during the first year.

As regards public buildings, timers and low flow devices as well as notices about water scarcity conservation are required. Industrial facilities must be provided with water recycling systems and in recognition of achieved water savings they may become eligible for reductions in water rates. Irrigation systems for public or private green areas must consist of close circuits and include low flow irrigation devices as well as time and soil moisture controllers. Failure to comply with any of the Law's requirements may lead to economical sanctions up to € 600,000 or even suspension of water supply.

As far as loses goes, detailed studies will be carried out to identify and eliminate leakage within the networks. Also, the distribution systems must be operated at the lowest pressure necessary in order to reduce loses.

In terms of institutional actions, The Region of Murcia has also made an important effort regarding water conservation by creating the Regional Water Advisory Council. Similar to the California Urban Water Conservation Council, the Regional Water Advisory Council of Murcia will monitor water conservation actions and will release an annual report including savings achievements and future initiatives. The Council will offer awards recognizing outstanding water savings and conservation practices.

4.5. Discussion

Traditionally water resources have been managed from the point of view of supply, yet today much effort is put into managing demand. Water use efficiency measures have proved themselves able to achieve important water savings and thus increase water supply availably that could be called on during dry seasons. Water use efficiency, also referred as water conservation, consists of the reduction of non-beneficial water uses such as losses and squandering. In addition to enhanced water management, less water use also means less energy use to convey and treat resources and wastewater.

In this section we've analyzed urban water demand and conservation practices in California and Spain. Despite both regions' similarities in terms of water supply, population and economical power, California water demand is double that of Spain. DWR and many public water agencies in California are carrying out aggressive conservation programs, unlike Spain where there is no comparable water conservation plan.

First, the State of California has made available a series of grants and loans for local agencies to implement water use efficiency measures. Potential water savings are estimated from 1.4 to 2.6 hm^3 per year by 2030 resulting from six levels of investment that range from $99 million to $236 million annually. Average unit cost of water savings ranges from $0.42/$m^3$ to $0.18/$m^3$. Overall marginal cost of water conservation drops as annual investment increases. As a result of locally cost-effective water efficiency programs, by 2030 urban water use would be 10% to 18% lower that it would be following the current trend. It is worth pointing out that the technical potential could achieve a 27% reduction, although the State estimates that it will not be cost-effective.

Second, the California Urban Water Conservation Council (CUWCC) encourages water agencies and urban customers to implement water use efficiency measures. The participating parties voluntarily sing an agreement known as the Memorandum of Understanding (MOU) by which they commit adopt the established Best Management Practices (BMPs) in order to increase water conservation. Since the Council was founded in 1991, the BMP have achieved over 2,255 millions of cubic meters in urban water savings.

Third, many local water suppliers also carry out their own water conservation programs at a local scale. The Metropolitan Water District of Southern California (MED) carries out one of the most outstanding urban water use efficiency programs. In order to mitigate the effects of the 1987-1991 drought, MWD called on conservation and therefore achieved 10% reduction in demand. During the last 15 years per capita water use has remained relatively stable as a result of continuous water conservation efforts. MWD's programs are based on the CUWCC's BMP as well as self-developed education campaigns and rebates programs. Residential, commercial and industrial customers may be reimbursed by MWD for total or part of the price when purchasing water use efficiency devices including landscape sprinklers, toilets, clothes washers, faucets and other innovative devices. Between 1900 and 2006 MWD invested over $187 million in residential, landscaping and commercial programs that achieved a total of 1,163 million cubic meters in water savings ($0.161/$m^3$ on average). The largest water savings occurred in the residential sector (80% of total savings) although landscaping water conservation is largely more cost effective.

Fourth, municipal water agencies such as Los Angeles Department of Water and Power (LADWP) provide their customers with additional rebates to encourage urban water conservation.

In Spain there is no public grant program comparable to that of the DWR any or independent conservation council similar to the CUWCC. However, the Ministry if Environment (MMA) does promote efficient water management laws and provides certain water conservation guidelines for every Hydrologic Region through its Drought Mitigation Plans (Planes de Sequia). As far as local initiative goes, in 2006 the Region of Murcia passed an aggressive water conservation law, which includes mandatory retrofitting for newly constructed buildings as well as 10% reduction in water bill for customers introducing volunteer upgrades. Moreover, Seville Water Agency provides a comprehensive list of water efficient devices and encourages retrofitting by pointing out potential water savings.

Similar programs to that of the MWD could be implemented although it is unlikely that the same results and cost-effectiveness of California would be achieved in Spain. In fact, more

urban water is used within the Metropolitan Water District service area than in Spain, yet Spain's is almost 40 times larger in terms of surface. As previously shown, the larger the water savings, the lower the unit cost. Thus, in order for Spain to achieve similar cost-efficiency and water savings to those of the MWD, conservation programs should be spread nationwide. Every local water agency would only be able to target little water conservation objectives, which would consequently increase the marginal cost of the savings.

Water marketing is one of the major tools in urban water management. However, due to its policy and financial complexity water marketing has not been tackled in this thesis. We strongly suggest that further studies should carry out a comparison of California and Spain's water rates and water rights.

4.6. Summary and Conclusions

To summarize, we point out the following conclusions:

- Per capita residential water use in California is 3.6 times higher than in Spain: 614 liters/person/day and 164 liters/person/day, respectively. The many reason for such difference is the fact that 70% of residential water in California is used outdoor for private landscaping, which is virtually nonexistent in Spain. In fact, indoor residential water use in California is 176 liters/person/day, which is only 8% higher than in Spain.
- Generally speaking, the price of urban water in Spain is much higher than in California, around two times higher depending on the region, rate block, etc. However, prices cannot be directly compared because they vary largely depending on the region and the water agencies involved. Moreover, prices charged to water users in Spain often include the cost of sewer conveyance and treatment.
- Commercial and industrial water demand in California is 2.4 times higher than in Spain. Furthermore, Spanish productivity doubles that of California: for every cubic meter used by industrial and commercial customers, Spain generates $1,504 but California only $838.
- Distribution systems in Spain are more inefficient than in California. Percentage of urban water loses in Spain is 18%, almost twice as much as the average in California.
- Since the drought of 1987-1991, California carries out aggressive urban water conservation programs at all levels, from local agencies to Department of Water Resources, to large retailers such as Metropolitan Water District and voluntary associations like the California Urban Water Conservation Council. In contrast, Spain's actions are limited to educational campaigns and establishment of general conservation guideless.
- Some Spanish water authorities such as Seville Water Agency and the Region of Murcia are moving towards water conservation strategies similar to those of California.
- Water conservation for large landscaping is 2.6 to 3.6 times more cost-effective and has a larger potential application compared to residential and commercial uses. Efficient irrigation devices like new generation nozzles have huge water savings potential and are cheaper to install compared to indoor devices, like toilets, clothes-washers and commercial machinery. Overall unit cost of water savings decreases with the level of investment.

In addition, we think the following recommendations should be followed:

- Assuming that Californians are not willing to give up their private green spaces, they should at least optimize irrigation by installing "smart irrigators" and grow native plants that are less water-consuming.
- Because the reasons for difference in commercial and industrial productivity between California and Spain have not been analyzed, future research in this area is strongly encouraged.
- Public water agencies in Spain should make major investments to improve their networks and cut down unnecessary squandering of water and energy entailed by losses. Only by reducing loses to the level of California, 500 hm^3 would be saved every year nationwide.
- California could save additional 142 hm^3/year if every urban area achieved water conservation at the level of MWD (2.6% of supply). Assuming equal percentage of savings, we estimate Spain's urban water conservation potential in 104 hm^3/year
- Spanish water agencies should carry out aggressive water conservation programs wherever this would be cost-effective. In addition, they should join ventures to create a nationwide conservation commission, similar to California Urban Water Conservation Council (CUWCC).
- Californian and Spanish water agencies should invest in large conservation programs targeting huge savings because they tend to be more cost-effective. Moreover, efficient landscaping programs should be prioritized, compared to those targeting commercial water use.