Important Water-Energy Nexus Considerations

A Sustainability Assessment of Water Supply in Two Municipalities of Costa Brava, Spain.

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- Aqualia
- Sorea

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ABSTRACT

The Costa Brava, the northeastern Mediterranean region of Catalonia, Spain, consists of 27 municipalities and is a hotspot for tourism during the summer months. Population increases from 240,000 to over 1 million between June and August. For Tossa de Mar and Lloret de Mar, two of the most visited municipalities along the Costa Brava, local water resources have proven insufficient during peak season since the 1970's. In order to meet the demand, at that time both municipalities imported treated groundwater from a richer basin further south. However, in the last decade issues of salt-water intrusion due to the overexploitation of the Tordera aquifer during the summer months has forced authorities to develop other supply alternatives such as desalination and water reuse.

While additional supply alternatives have proven successful mechanisms of relief for the Tordera aquifer, they come with attached energy intensity consequences that jeopardize the overall sustainability of the sources. This study examines the energy consumption of the different supply sources to Tossa de Mar and Lloret de Mar. The goal of the report was to evaluate the fluctuation of supply across the year, and to look specifically at the relative energy costs of each of the major sources used to meet water demand,. The overall energy consumption of the local wells, the wells in the Todera aquifer, desalination, and water reuse were assessed and compared. Extraction, treatment, and distribution data sets for volume (m^3) and energy consumption (kWh) were compiled monthly between the years 2007 and 2011 for each water supply source. From these data, ratios (kWh/m^3) were calculated to determine specific and relative energy consumptions. Desalination proves the most energy intensive supply source, followed by Tordera aquifer, water reuse and local wells. Tertiary treatment is shown to offer significant energy savings over desalination when energy consumption values are broken down by the individual pumping, treatment, and conveyance costs.

In order to obtain truly sustainable water resource management, authorities must consider the energy consumption components throughout the water supply life cycle. First, a push towards sectorial integration is required. In Spain, water policy is managed in a variety of ways from the national level all the way down to the municipal level. Energy policy on the other hand is primarily regulated at the national level. Better integration between the two sectors is required. Specifically, representation from the energy sector must be present throughout each level of the complex water hierarchy. Second, favoritism toward supply-oriented management isolates important demand management considerations that have consequences on overall energy consumption. Incentivizing water conservation at the individual user level proves an important step towards achieving true sustainability. Incentivizing the user decreases demand and offers a connected energy conservation component. Decrease in demand results in a decrease in energy needs. Therefore, conservation and demand-management strategies are also relevant for sustainable water supply.

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INTRODUCTION

Water and energy are critical components of development. Civilizations have come to being based on the interconnectivity of these two important sectors. Before electricity all water supply was gravity fed, positioning human settlements downhill from surface water sources. Electricity allowed for settlement construction away from natural water sources as pumps and distribution networks were constructed (McMahon & Price, 2011). Modern water supply networks were traditionally a response to unsanitary conditions and fighting reoccurring epidemics such as typhoid fever, cholera, and dysentery in industrializing urban environments. Modernized infrastructure presented a solution for urban dwellings in which large dams, aqueducts for storage and pumping mechanisms and transferring water from far distances aided the distribution of new fresh water source into the cities and vast networks of sewer system to discharge waste out of the clustered areas (Ruiz-Villaverde et al., 2013). As technology advanced, large and complex centralized systems developed around both water and energy resources (Brooks 2006). Reflecting growth and development projections, pipelines, pumps, dams, and irrigation canals provided water to cities, towns, and farmlands.

Near the end of the 20th century, a global shift towards the need for sustainable resource management took flight. The overexploitation of surface and groundwater world brought sustainable water management to the forefront of this discussion. International and national policies began to shift away from large-scale interbasin water transfer projects to promote new management strategies. Broad umbrella policies such as Agenda 21 and the European Union's Water Framework Directive called for countries to implement new water resource management plans that would provide relief to overexploited local water resources. Laundry lists of solutions were presented including education awareness campaigns, real cost pricing mechanisms, and new alternative supply solutions such as desalination and water reuse.

Influenced by the new management trend, Spanish water policy started adopting recommendations outlined in the international and supranational policies. The management mentality maintained a supply-oriented focus. Specifically, it looked to desalination and tertiary treatment plants as a means to relieve stress from the overexploited aquifers and rivers. Although desalination and tertiary treatment have proven to relieve stress from the fresh water resources, these alternatives have not come without attached sustainability consequences. Specifically, the energy consumption and funding requirements are significant.

Tossa de Mar and Lloret de Mar, two small coastal towns along Spain's Northern Mediterranean coast, provide interesting case studies for looking at how the historical overexploitation of groundwater has led to the current supply infrastructure makeup. This paper completes a full energy consumption analysis of the water supply life cycle for these two municipalities. Energy consumption is calculated for the extraction, treatment, distribution, wastewater collection, wastewater treatment, tertiary treatment, and the disposal of wastewater back to the natural environment. Final calculations prove that supply alternatives have very different energy costs. According to the supply sources reviewed in this paper, desalination is the most energy intensive water supply source. Difference in treatment and conveyance energy costs proves to be an important factor for water authorities to keep in mind, when choosing which supply alternative to construct. In the case of Tossa de Mar and Lloret de Mar, tertiary treatment proves a more sustainable source over desalination when energy consumption values are broken down by the individual pumping, treatment, and conveyance costs.

Policy gaps across each institutional level jeopardize the sustainability of water resource management at the local level. First, favoritism toward supply-oriented management isolates important demand management considerations that have consequences on overall energy consumption. While it is necessary that supply alternatives are included, incentivizing water conservation at the individual user levels proves an important step towards achieving true sustainability. Not only does incentivizing the user result in decreasing demand but it also offers a connected energy conservation component. Decrease in demand results in a decrease in energy needs for pumping, treating, and conveyance, and in-home hot water and cooling requirements year round. Therefore, conservation and demand-management strategies become extremely relevant for the overall sustainability of the water supply source and not just the health of the aquifer.

It is clear that water and energy are closely aligned. Both sectors rely heavily on each other for production. Water supply decisions come with attached energy consequences and vice versa. However, policies surrounding these two sectors are enacted independent of each other. The adoption of alternative supply sources come with attached energy consequences. A push towards sectorial integration is required if authorities want to obtain sustainable water management. It will require new incentive structures to promote water and energy efficiency at the user level. More broadly though it is an issue of political disconnect. In Spain, water policy is managed at the national level all the way down to the municipal level. Energy policy on the other hand is primarily regulated at the National level. Better integration between the two sectors is required. Specifically, representation from the energy sector is required throughout each level of the complex water hierarchy. The fragmentation of Spain’s current decision-making structure may prove challenging for such venture but if the two sectors do not find the proper avenue of integration then future supply decisions will continue to produce energy intensive, unsustainable results.

HISTORICAL CONTEXT

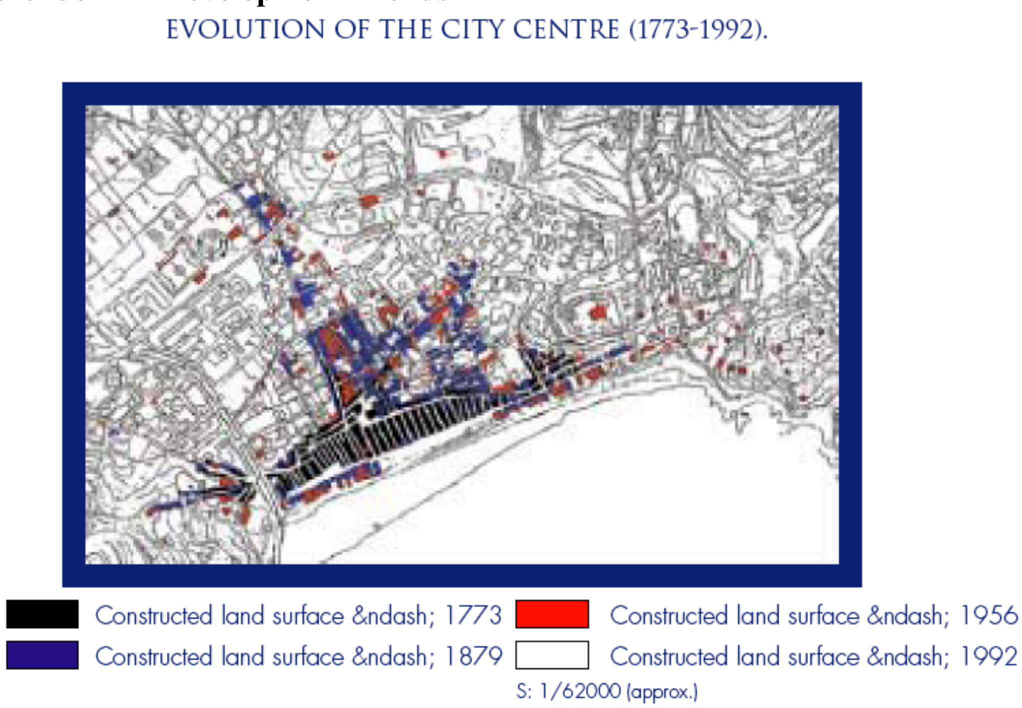
The northeastern Mediterranean region of Catalunya, Spain, is a hotspot for tourism during the summer months. Between June and August the population increases from 240,000 people to over 1 million (Consorci of Costa Brava, 2011). History suggests that economically driven land use policies has resulted in inadequate fresh water supply during the summer months (Breton & Sauri-Pujol, 1997; Morrison & Dickinson, 2008). Until 2005 when the NHP was updated, disconnect existed between land use planning and water resource management. Lack of coordination between regional planners and policy makers within the Ministry of Environment and the River Basin Authorities produced urbanization trends that did not match water resource supply realities. Authorities were obligated to provide water supply even when resources were insufficient to meet the projected growth of the new development (Menéndez, 2010). The over-provisions of land beginning in the1960s led to the construction of expansive urbanizations of second home vacation dwellings into the mountains by the mid 1980s (Morris & Dickinson, 1987). Between 1960 and 1991 the Costa Brava's population grew between 50-150% (Mas, 2011). The following decade it saw an additional 7.8% increase in second home vacation owners and a 10.3% increase in the overall residential population motivated by the rapidly growing tourist industry (Sardá et al. 2004).

Water Supply and Development

The Southern portion of the Costa Brava was the first region that experienced mass development along the coast. Lloret de Mar and Tossa de Mar became important tourist destinations starting in the 1960s. The evolution of water supply mirrors the development trends of these two municipalities. First, Lloret de Mar was the fastest growing tourist destination along the Costa Brava starting in the 1960s. It was the first municipality to recognize that the water supply sources were insufficient to meet the growth trends of the time. In the early 1900s Lloret de Mar only had approximately 3200 inhabitants. Its population grew 150% between 1960 and 1991 (Mas, 2011, p. 20) with a specific 143% increase in second homes between 1970 and 1981 (Fresno 1983; Morris and Dickinson, 1987). Figure 1 demonstrates that by 1992 urban expansion had occurred along the coast and back up into the mountains. It became the most touristic region along the Costa Brava. The increase in tourism during the summer months is the main culprit for the increase in water consumption. Between 1996 and 2001 the population increased 20.3% with a water consumption increase rate of 12.10% (Sardá et al., 2004). By 2011 Lloret de Mar had a resident population of 40,000, which grew to approximately 150,000 during the summer months (Buixeda et al., 2011). Figure 2 shows that over a five-year span, average water demand during summer months nearly doubles in comparison to winter.

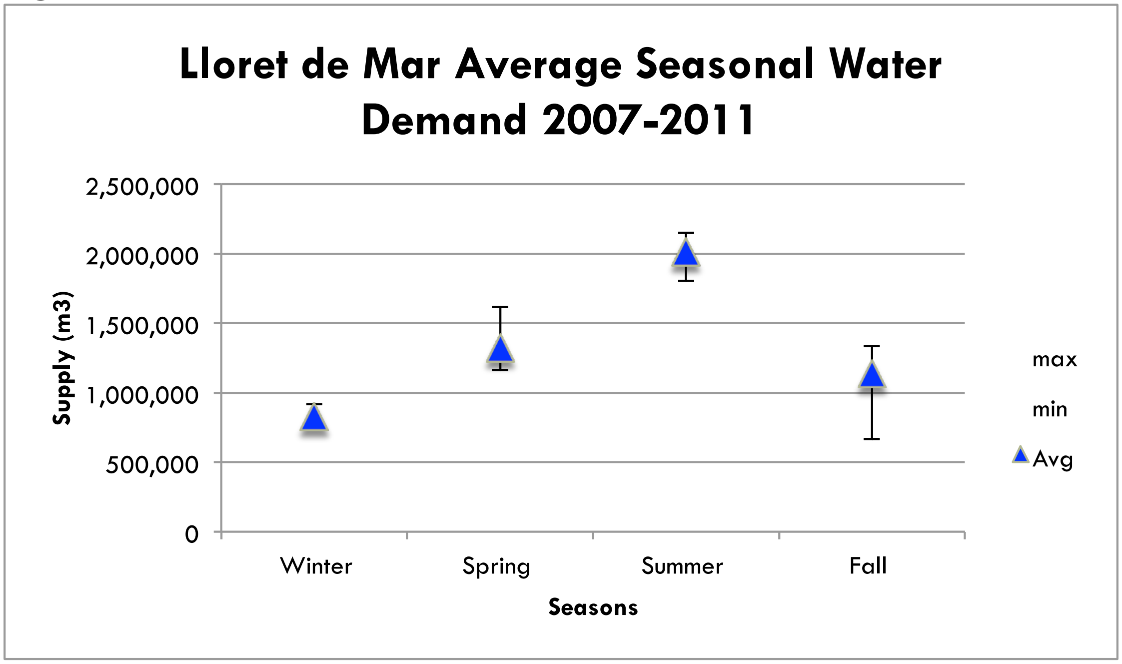
Tossa de Mar's development similarly diminished local water availability even though it curtailed the mass tourism trend experienced by neighboring Lloret de Mar. From 1950-1970 the population increased from 1800-2500. By the 1970s, Tossa de Mar recognized the need for additional water supply sources, as local wells were no longer sufficient to meet increasing demand during the summer months. By 2011 it had a total of 6,000 registered residents and a total population of 60,000 during the summer months (Couso et al., 2011). This increase in both permanent residents and second homeowners meant a greater demand for local resources, specifically fresh water resources. El Centre d'Estudis Avançats de Blanes' statistical analysis shows a relationship between an increase in residential population between 1996 and 2001 and an increase in water consumption. In Tossa de Mar, the population increased 13.31% with a corresponding water consumption increase of 9.98% (Sardá et al., 2004). Like Lloret de Mar, Figure 3 shows demand for water is highest during the peak summer months when tourists and second home owners come to enjoy the beautiful beaches and warm weather that the Catalan Mediterranean coast has to offer.

Figure 1
Lloret de Mar Development Trends



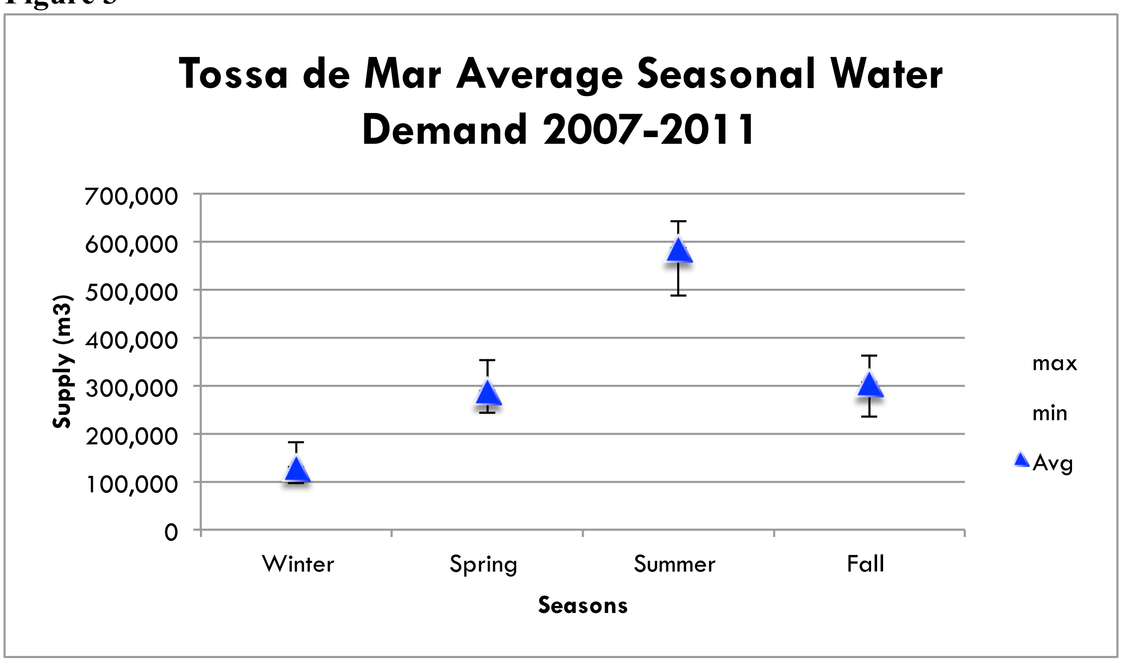
(Source: Agenda XXI Lloret, 2010)

Figure 2



(Source: Own elaboration with data from ETAP and ITAM)

Figure 3



(Source: Own elaboration with data from ETAP, ITAM, and Sorea)

Water Supply Sources

Lloret de Mar and Tossa de Mar rely on groundwater as the primary source of supply. The Mediterranean coast only encompasses 10% of the country's total productive groundwater resources. (Cantera et al., 1981); yet as observed in Southern Costa Brava, urban development depends significantly on this subterranean source of water throughout the region. According to the Catalan Water Agency, 60% of urban water use comes from groundwater sources. Within the Internal Watershed in which the Costa Brava resides, 40% of overall urban water allocation comes from subterranean sources (ACA, 2005).

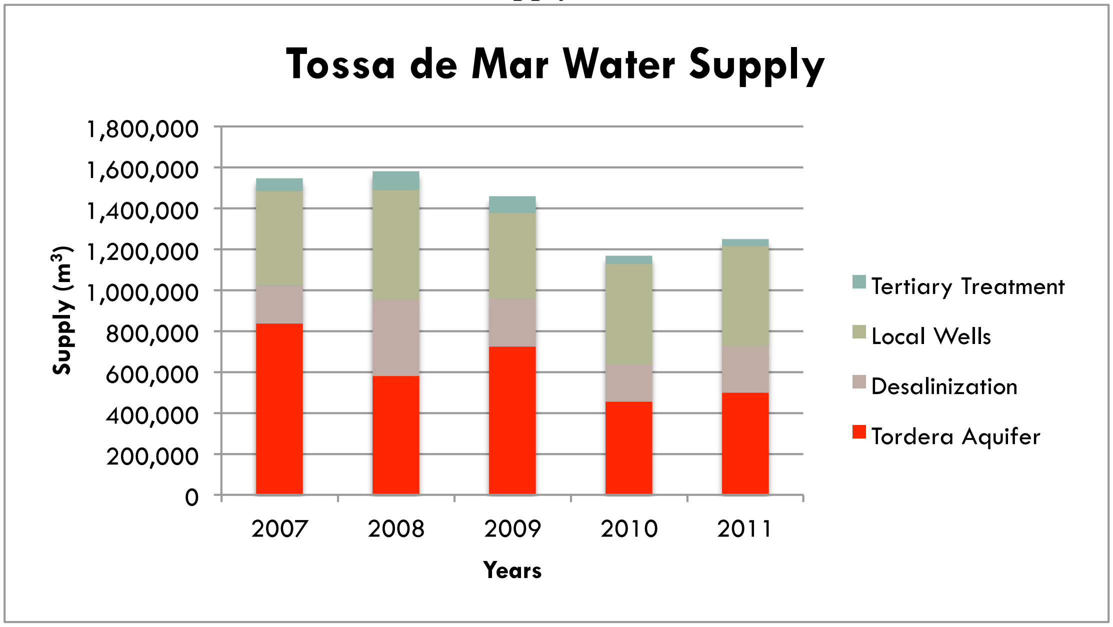
For Tossa de Mar and Lloret de Mar, demand for water resources coincided with the driest part of the year, proving local water supplies insufficient during the summer months. Therefore, both municipalities were forced to extend their water supply networks outside municipal boundaries and import treated groundwater from a richer basin further south. By 1980 supply traveled as much as 16 kilometers to the coastal towns from the Tordera Aquifer (Mas, 2011). For Lloret de Mar this was the only supply source available until the early 2000s. Tossa de Mar, on the other hand, exploits 30% of its municipal supply from five local wells that reside within the municipality (pers. comm Jordi Couso, 2012).

Complications arise as authorities are pressed to meet growing demand for fresh water resources when peak tourism season coincides with the driest part of the year. As previously discussed, the Mediterranean coast has a variable climate. It experiences long dry summers with sporadic rainfall in autumn and winter (Martinez-Cortina, 2010). Issues of water scarcity arise when demand for water is high; yet precipitation levels are low. The overexploitation of groundwater water resources during the summer months can lead to salt water intrusion of the aquifer. This affects the quality of the water. The Tordera Aquifer, both municipalities' main supply source, is a porous unconsolidated alluvial aquifer near the coast. This specific typology experiences great pressure during the summer months and risks of salinization from urban demands are high during peak season (ACA, 2005). The overexploitation of coastal aquifers poses a risk for salt-water intrusion. Disrupting the natural equilibrium between the freshwater and saltwater interface due to over pumping allows salt water to enter, salinates the freshwater and leaves it undesirable for human consumption (Khublaryan et al., 2008; Kirsch, 2006). In the 80s the Costa Brava struggled with poor water quality. Salinization due to overexploitation and the presence of magnesium and iron was a critical concern for municipalities (Mas, 2011). From 1998-2002, the Tordera aquifer's salinization levels increased ever summer, following the trends of demand (pers. comm. ACA, 2013).

Based on the sensitive typology of the local aquifer and the risk of overexploitation during peak tourism season, alleviating pressure from the Tordera Aquifer and the local coastal aquifers became an essential management task for the municipalities along southern Costa Brava. Article 4bii of the Water Framework Directive commits Member States to restore all groundwater and ensure that annual average rate of extraction does not exceed the rate of recharge (WFD, 2000). As it is obligated to do so under law, Catalunya's 2010 water resource management plan follows many of the WFD's prescriptions. Aquifer health is measured on a scale ranging from very good to very poor. As prescribed by the Directive, the plan's objective strives to achieve "good" status by 2015 (ACA, 2010). As a means to comply with WFD and to ensure the contaminated water did not affect the tourism industry, authorities searched for solutions to avoid overexploitation of groundwater sources, risks of salt-water intrusion, and drought management response mechanisms across the Mediterranean basin (pers. comm. ACA, 2013).

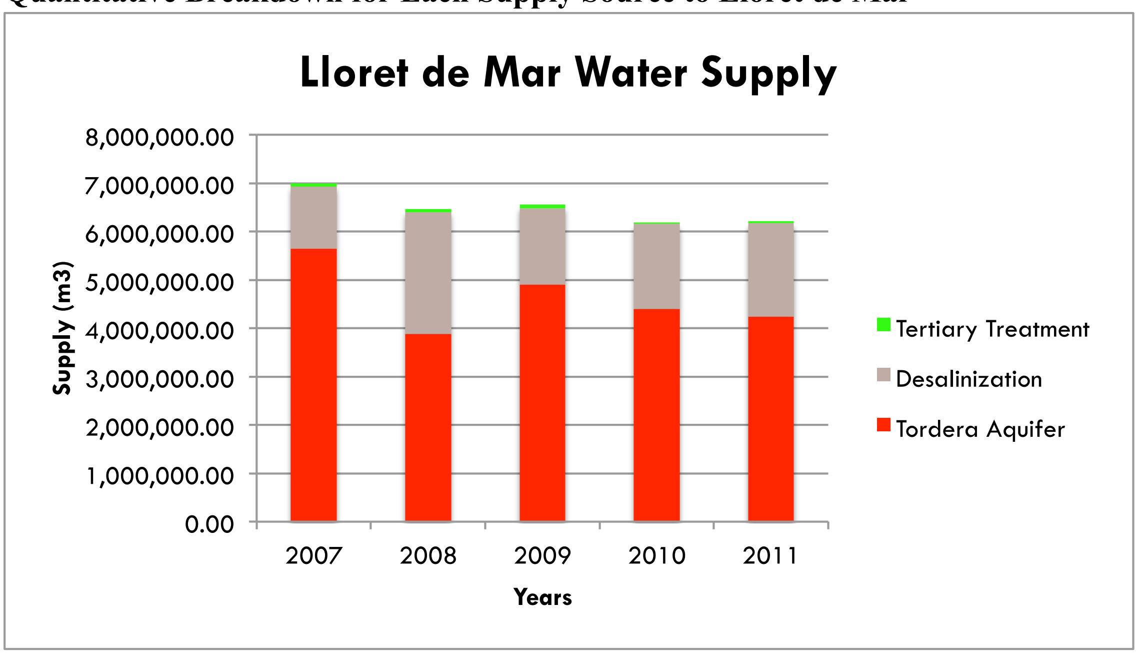
The construction of a desalinization plant and water reuse facilities at both municipal wastewater treatment plants were determined the most appropriate supplementary responses. According to a study conducted by Cambra de Comerç, Indústria i Navegació de Barcelona, the Costa Brava produced 6.2hm3 of wastewater in 2009, representing 21% of the total volume of treated wastewater (Dolz & Armengol, 2011). This increase in supply is significant for the water stressed region. Not only does it provide the municipalities with additional urban use supplies such as street cleaning and park irrigation, but also more important it is an additional source for recharging an aquifer. The Tordera aquifer has the capacity to take up to 3 million m^3 of reclaimed water. As of 2006, 56% of water reuse was used to replenish the aquifers (Serra & Sala, 2007). Additionally, the desalination plant in Blanes extracts water from the sea, treats the salinated water through the process of reverse osmosis and then conveys this water to the water treatment plant in Tordera where it is mixed in with the treated water ready for delivery. The desalinated water is a supplementary source whose quantitative supply is directly connected to the health of aquifer during peak tourism season. As a mechanism to prevent the salinization of groundwater, the Water Agency of Catalunya (ACA) determines how much desalinated water is necessary to compensate for the overexploitation of the aquifer during the summer months. While the plant has the capacity of 20 hm^3 per year, the amount supplied varies annually based on annual precipitation and salinization levels of the aquifer (pers. comm. ACA, 2013). Figure 4 and Figure 5 show the portion of supply that comes from each individual supply source for both municipalities.

Figure 4
Quantitative Breakdown for Each Supply Source to Tossa de Mar



(Source: Own elaboration with data from ETAP, ITAM, Tossa de Mar Wastewater Treatment Facility, Sorea, and Consorci Costa Brava)

Figure 5
Quantitative Breakdown for Each Supply Source to Lloret de Mar



(Source: Own elaboration with data from ETAP, ITAM, Lloret Wastewater Treatment Facility, and Consorci Costa Brava)

It is important to recognize a few factors regarding the graphs. First, Tossa de Mar's access to local wells within the municipality makes it less reliant on the Tordera Aquifer. On the contrary, the absence of local supply in Lloret de Mar forces the municipality to rely solely on external sources, of which the most important is this groundwater source. Since it only has this source and has greater demand than Tossa de Mar, it receives a greater proportion of the overall desalinated water sent to the water treatment plant in Tordera. Second, the relationship between drought response and increased supply is expressed. For example, the Mediterranean region experienced significant drought the second half of 2007 until March of 2008. Therefore, both municipalities receive a greater supply of desalinated water in 2008 than any other year. This aids aquifer replenishment in order to avoid salt-water intrusion that will occur if the aquifer is overexploited over multiple years while the region consistently experiences periods of variable rainfall and drought (pers. comm. ACA, 2013). Last, it is clear that desalination has been the preferred supply alternative over tertiary treatment in both municipalities. Although Tossa de Mar only has about 1/5th the demand for water as Lloret de Mar, its overall portion of tertiary treated water supply is greater than that of Lloret. Reasons and analysis for these differentiations will be discussed later in the paper.

WATER-ENERGY NEXUS ANALYSIS

Increased demand for fresh water resources during summer months, increasing risk of drought, and the European Union's Water Framework's objective to achieve "good" ecological status by 2015 forced Catalan water authorities to search for new supply alternatives that would both eliminate salt water intrusion problems and secure adequate supply during peak tourism season along the Costa Brava. It looked to desalination and tertiary treatment plants as a means to relieve stress from the overexploited aquifers and rivers. Although both sources have proven to relieve stress from the Tordera Aquifer, the energy consumption and funding requirements are significant. The lack of consideration for energy consumption throughout the decision-making process jeopardizes the sustainability of the water supply life cycle.

Global Context

A recent analysis by OECD (2012) recognizes that a significant policy gap exists in water and energy policy. The connection between water and energy was absent throughout the important supranational and national policies at the turn of 20th century. As urbanization and development increases, municipalities search for new methods to secure supply for current and future generations. This has resulted in the construction of water supply infrastructure with varying energy costs.

The energy intensity of the water life cycle depends on the context in which it is evaluated. The source and method of extraction and treatment varies based on water resource availability. Global, regional, and local points of view all produce varying energy intensity values. Technology, infrastructure, topography, and population all play important roles in the overall water-energy nexus. Table 1 displays that energy-for-water relationships change within region specific contexts when discussing the energy costs of extracting, treating, and distributing both potable water supply and wastewater. First, it is clear that energy consumption should be a serious concern for municipal level water resource managers. For example, it is typically it is the first or second greatest cost for water utilities in the United States (McMahon & Price, 2011). Additionally, urban areas can have a significant degree of variance. Source of the water, the distance it travels, the topography the supply travels over, the population of the area, and technology adopted all could account for the difference. For instance energy consumption depends on the slope of the landscape. Energy consumption related to conveyance, the distribution of water, can vary between neighboring cites based on hilly or mountainous terrain. In Tijuana, Mexico, the water life cycle is almost five times as energy intensive than other Mexican cities due to pumping requirements over its mountainous terrain (Plappally & Lienhard, 2012). When observing energy-water relationships it is important to keep these types of conceptual factors in mind.

Extraction, Treatment, and Conveyance technologies differ depending on local resource availability. For example, groundwater supply's main electrical cost is the extraction stage. Energy expended correlates to the depth and pressure of the aquifer during the pumping stage (Plappally & Lienhard, 2012). As fresh water becomes scarce energy costs of extraction can increase as pumping deeper into the aquifer becomes necessary to exploit the resource. As a supplement to groundwater, desalinization has become an attractive supply alternative. This technology has proven to be very energy intensive. The intensity primarily attributes to the salinity level of the seawater. Reverse osmosis has proven to be less energy intensive than thermal distillation; however, it is still a significantly high-energy intensive process. The energy intensity of the treatment process removes a saline content of approximately 35,000 ppm to meet European Union drinking water requirements of less than 500 ppm. The process is expected to demand anywhere between 2.4-8.5 kWh/m^3 (Von Medeazza, 2005, Plappally & Lienhard, 2012, Sala & Serra, 2004). Electricity alone can account for 55% of the overall cost of the desalinization process (Molina & Casañas, 2009). Table 2 shows that desalination has the highest range of energy consumption of all other sources. Last, water reuse or water recycling has become an attractive alternative to increase supply in water scarce regions. This process entails an additional step to traditional secondary wastewater treatment. A tertiary treatment process improves the water quality to either non-potable or potable standards. Wastewater that would traditionally be discharged directly back into the ecosystem becomes available for either non-potable uses such as irrigation or aquifer discharge or potable uses if an advanced treatment like reverse osmosis is applied. As conveyed in Table 2 energy consumption of tertiary treatment can vary considerably depending upon the specific treatment applied and if the treated wastewater is brought to drinking quality standards.

Table 1
Water Life Cycle Energy Use Percentage of Total Energy Use

	Percentage of electricity or energy use	Reference
Global	7%	(Plappally & Lienhard, 2012)
Spain	5.8%	(Hardy et al., 2012)
Australia	0.2%	(McMahon & Price, 2011)
California	5%	(Hussey & Pittock, 2012)
Urban Areas	1%-18%	(Olsson, 2012)
Municipalities (USA)	35%	(Elliot, 2005)

Table 2
Energy Consumption of Various Global Sources of Water Supply

Source of Water	Range of energy consumption kwh/m3	References
Surface Water	0.0002-1.74	(Sala and Serra 2004); (Plappally and Lienhard 2012);
Groundwater	0.37-1.44	(Sala and Serra 2004), (Plappally and Lienhard 2012);
Desalinization (reverse osmosis)	2.4-8.5	(Plappally and Lienhard 2012); (Sala and Serra 2004); (Von Medeazza 2005)
Wastewater treatment	0.38-1.122	(Sala and Serra 2004); (Plappally and Lienhard 2012)
Reclaimed or Recycled Water	0.18-0.63; 1.0- 3.8 (Reverse Osmosis)	(Schroeder et al 2012); (Plappally and Lienhard 2012)

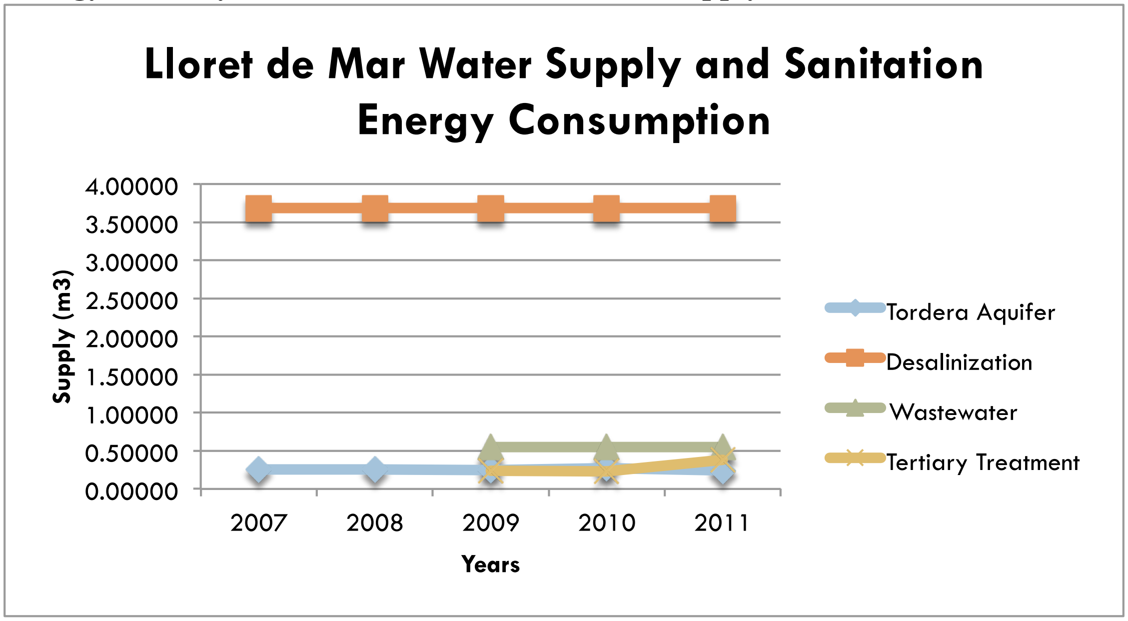
Local Context

As discussed throughout this paper, the adoption of these new supply alternatives have come with attached energy costs. In this paper, energy consumption of potable water production and wastewater treatment is calculated by kWh of electricity per cubic meter of water (kWh/m3). The flow rate and energy consumption data was provided by each individual treatment facility and Consorci Costa Brava, the regional wholesale municipal water provider. The water life cycle in this paper is defined in anthropocentric terms. Energy consumption is calculated for the extraction, treatment, distribution, wastewater collection, wastewater treatment, and reclamation of wastewater known as tertiary treatment, and the disposal of wastewater back to the natural environment. It is important to note that treated wastewater is not a supply source. However, when an additional treatment process is applied it produces reclaimed water. This advanced treatment process provides both municipalities a new and additional non-potable supply source.

Results

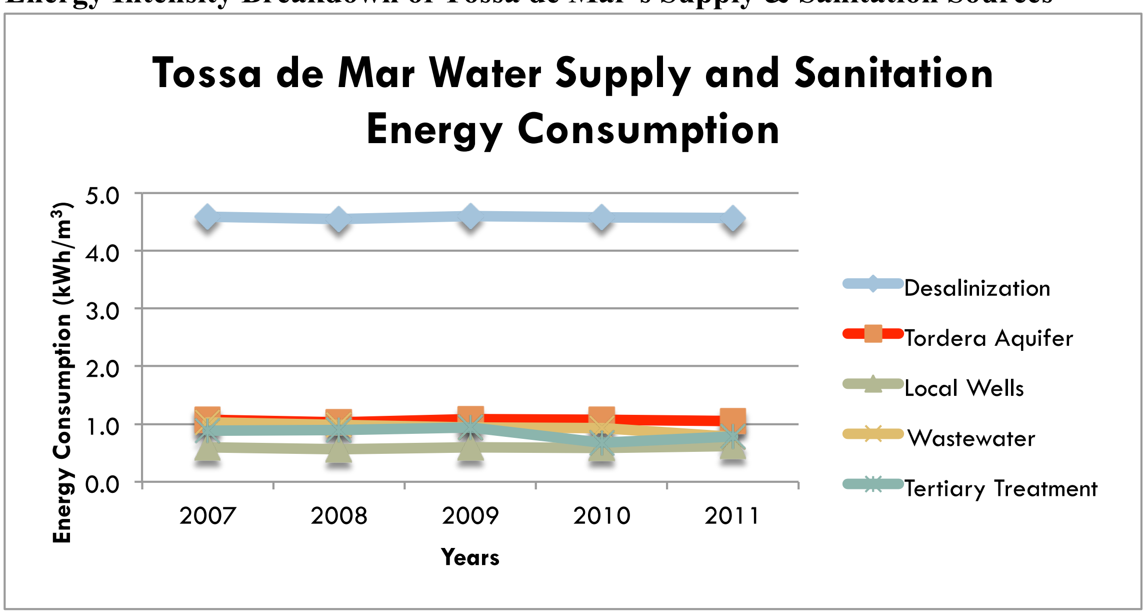
Supply alternatives have very different energy costs. According to the supply sources reviewed in this paper, Figure 6 and Figure 7 show that desalination is the most energy intensive water supply source. Analyzing the entire water life cycle of extraction, treatment, and conveyance to end users in Tossa de Mar in 2011, desalinization proves 4 times more energy intensive than the supply from the Tordera Aquifer, 7 times more than local wells, and between 5 and 6 times more energy intensive than water reuse. Applying the same energy consumption analysis for supply in Lloret de Mar, desalination proves more than 6 times more energy intensive than supply from the Tordera Aquifer and more than 10 times more energy intensive than water reuse. It must be noted that tertiary treatment energy consumption data displayed in Figure 6 does not begin until 2009. Before May 2008, a simpler treatment system was applied to the secondary effluent in Lloret de Mar. The reclaimed water was treated through chlorination and delivered directly to a near by golf course. This required no additional energy; however, it produced lower quality water in terms of turbidity and suspended solids. After May 2008, the wastewater treatment facility adopted the traditional tertiary treatment that results in higher energy costs (pers comm. Consorci Costa Brava, 2012). The system includes: coagulation-flocculation, lamella settling, microscreening, and a combined disinfection process using sodium hypochlorite and UV light at a maximum dose of 37 mJ/cm^2 (Buixeda et al., 2011).

Figure 6
Energy Intensity Breakdown of Lloret de Mar's Supply & Sanitation Sources



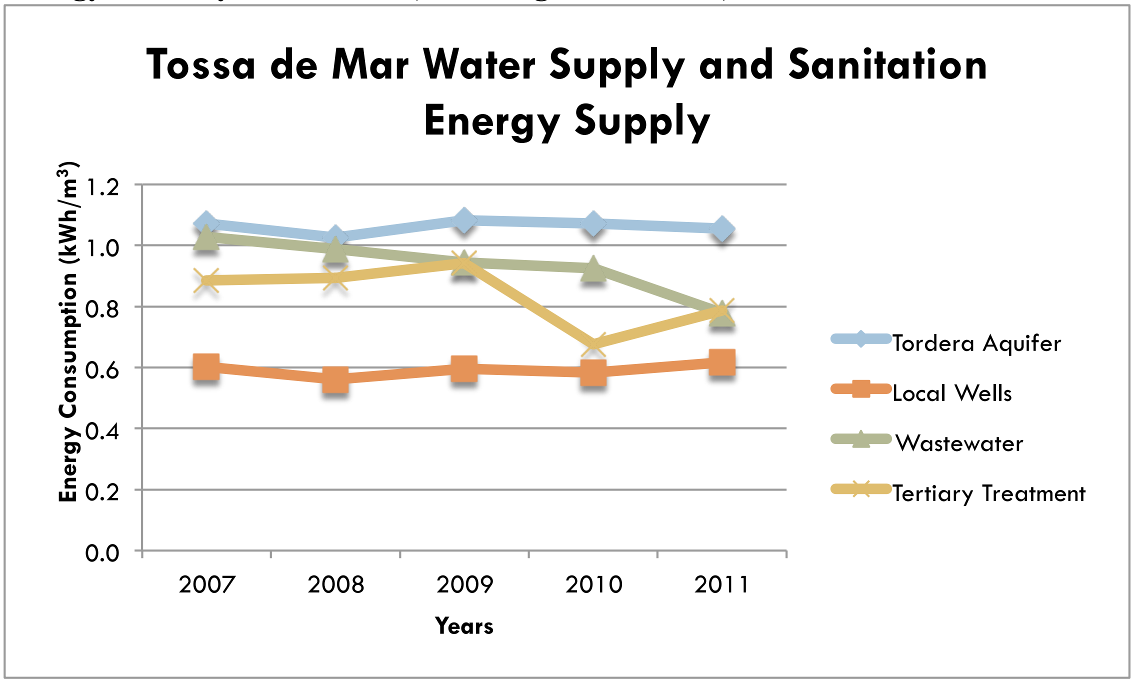
(Source: Own elaboration with data from ETAP, ITAM, Lloret de Mar's Wastewater Treatment Facility, and Consorci Costa Brava)

Figure 7
Energy Intensity Breakdown of Tossa de Mar's Supply & Sanitation Sources



(Source: Own elaboration with data from ETAP, ITAM, Tossa de Mar's Wastewater Treatment Facility, Sorea, and Consorci Costa Brava)

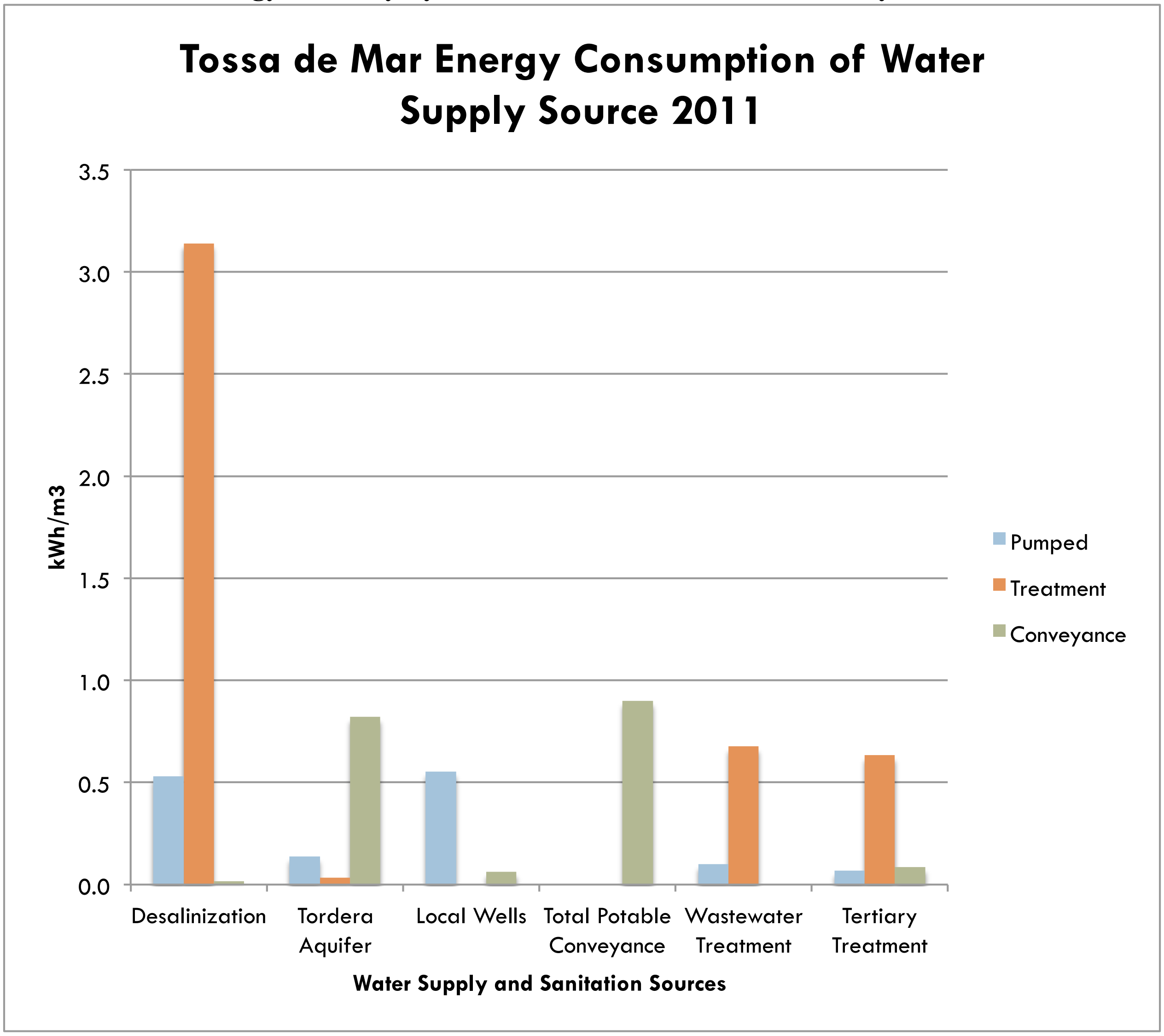
Figure 8
Energy Intensity Breakdown (excluding desalination)



(Source: Own elaboration with data from ETAP, ITAM, Tossa de Mar's Wastewater Treatment Facility, Sorea, and Consorci Costa Brava)

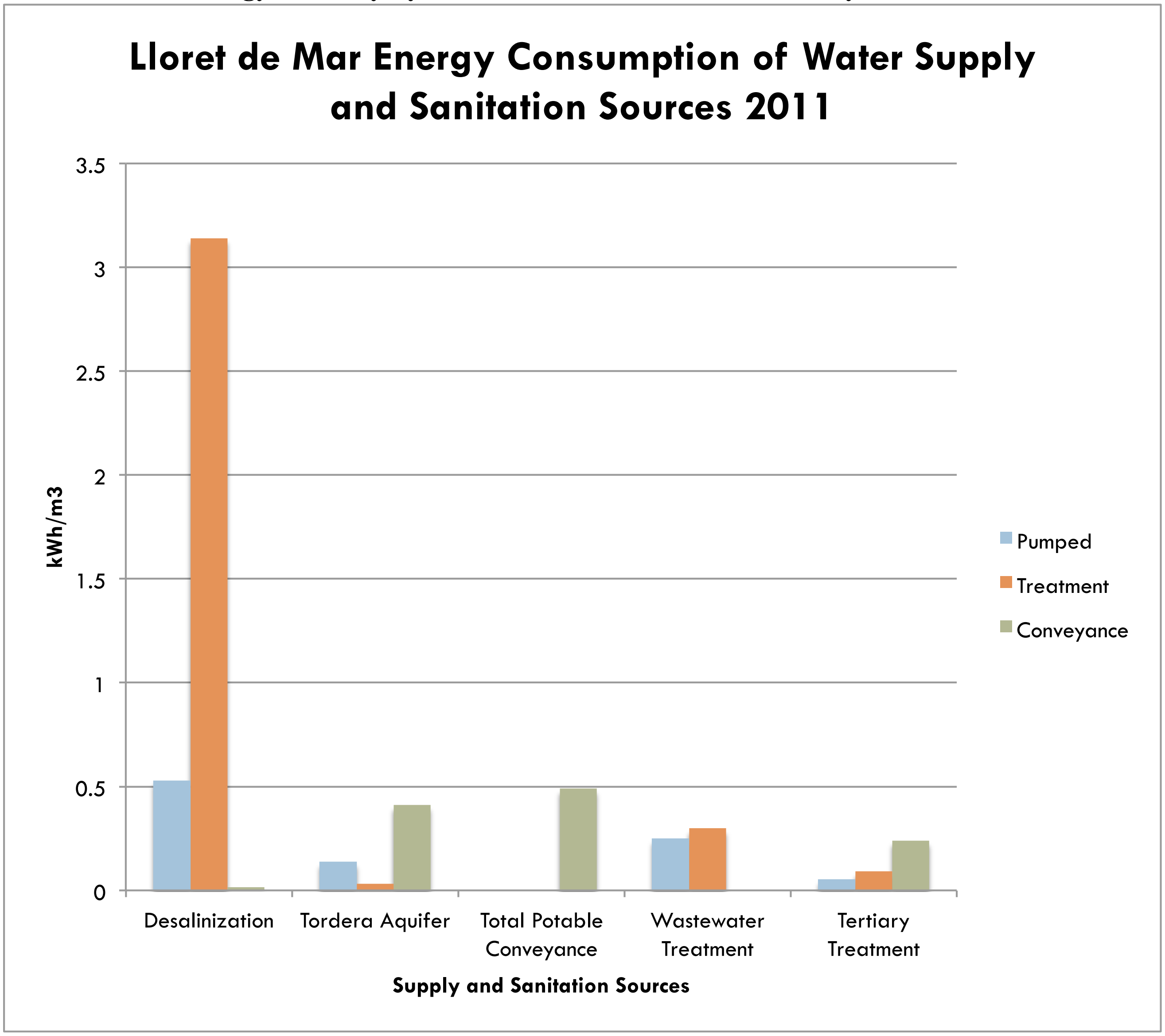
Tossa de Mar and Lloret de Mar rely on various supply sources throughout the year. Each source conveys a specific proportion of the overall supply and has varying energy consumption values. When the system is compartmentalized even further, the results describe why the different supply and sanitation sources vary in energy consumption. Extraction of the source, treating the water to potable or non potable standards, and distributing the water from the treatment plant to the final user all have independent energy consumption values. Figure 9 and Figure 10 break down these values for both municipalities.

Figure 9
Breakdown of Energy Intensity by Extraction, Treatment, and Conveyance



(Source: Own elaboration with data from ETAP, ITAM, Tossa de Mar's Wastewater Treatment Facility, Sorea, and Consorci Costa Brava)

Figure 10
Breakdown of Energy Intensity by Extraction, Treatment, and Conveyance



(Source: Own elaboration with data from ETAP, ITAM, Lloret de Mar's Wastewater Treatment Facility, Aqualia, and Consorci Costa Brava)

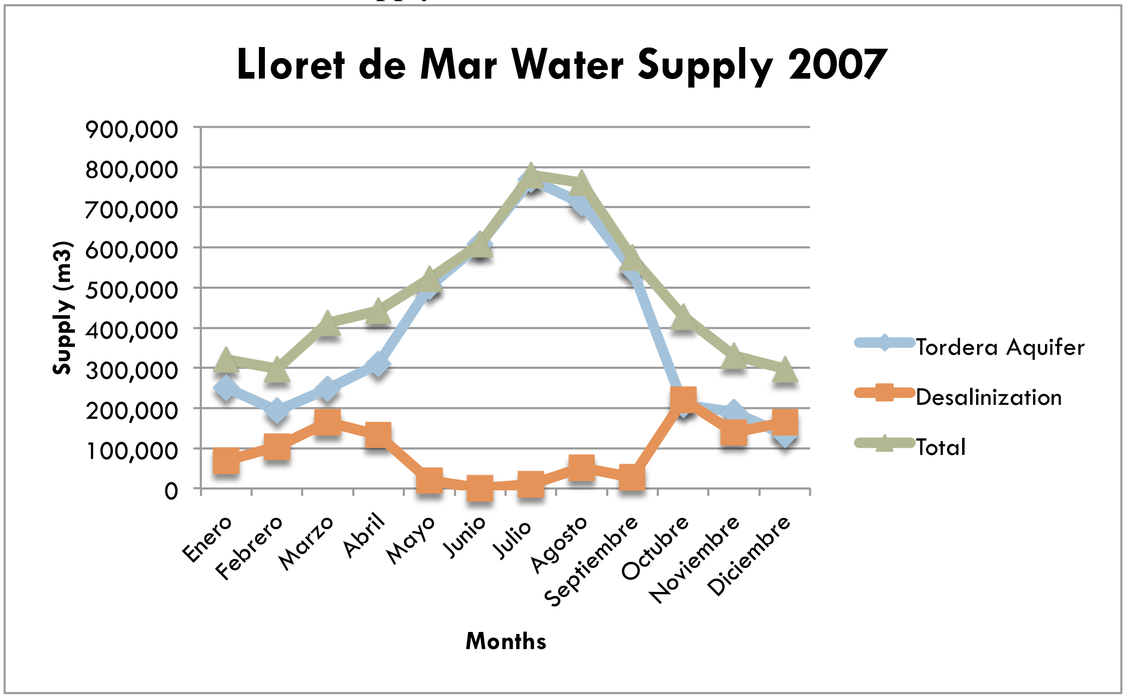
As discussed previously, it is important that regional context is taken into account when analyzing water supply sources and their attached energy consumption values. The geography along the Costa Brava is very hilly. Urban settlements expand throughout the coastal hills. Therefore, more energy is required to pump water up the mountains to arrive at the municipality. In Tossa de Mar, Figure 9 shows water supply from the local wells proves the least energy intensive source. However, the local source is insignificant to meet annual demand based on the dramatic increase in population during peak tourism season. Like Lloret de Mar, the water authorities have had to look for supply outside of the local wells.

The compartmentalization of the energy intensity of each step in the overall water supply life cycle provides insight into the similarities and differences between the supply systems of the two municipalities. For example, the summation for conveyance of each potable supply source to Tossa de Mar is higher than to Lloret de Mar for three reasons. First, Tossa de Mar is further away from the groundwater source than Lloret de Mar. Next, the height over the mountainous terrain is greater. Last, 1/10th of Lloret de Mar's water supply is gravity fed from the Tordera Aquifer to the municipality; therefore, this portion requires 0 energy (pers. comm. Consorci Costa Brava, 2012). Next, the energy intensity of potable supply conveyance is greater than conveyance of tertiary treatment. Last, it is clear that the treatment process for desalination is significantly higher than any other value throughout both supply networks. This is due to the application of reverse osmosis that converts highly saline water into a fresh potable source.

The difference in energy consumption rates produces varying consequences for the overall sustainability of supply decisions. It is important that water authorities take each individual component of the overall water life cycle supply chain into consideration when determining the most sustainable management solution. Although the advantage of desalination is to have a guaranteed supply source in times of drought, the energy intensity of desalination makes it a very expensive, and, in a part of the world beset by economic challenges, an inherently uncertain supply alternative. Therefore, water authorities in Catalunya are forced to limit its supply (pers. comm. ACA, 2013). This significantly compromises the overall utility of this alternative technology. The high cost of energy becomes extremely significant in times of economic crisis as Spain is currently experiencing. It becomes a challenge to effectively operate this supply source.

If the desalination plant is not in operation for one or two years then it has little consequence on the aquifer's health. Minimized supply from desalination during one or two drought years does not greatly affect the health of the aquifer. According to ACA, no damage to the Tordera Aquifer occurred during the drought period between 2007-2008 even though the Blanes desalination plant was shut down for retrofitting construction during peak tourist season as shown in Figure 11 (pers comm ACA, 2013). Rather, the accumulation of overexploitation over several years created problems of salt-water intrusion. However, as water availability is predicted to only become more variable in the future due to climate change, authorities must question the viability of this supply alternative whose sustainability is subject to economic shock.

Figure 11
Lloret de Mar's Overall Supply from Desalination versus Groundwater in 2007



(Source: Own elaboration with data from ETAP & ITAM)

The energy intensity of the conveyance step is another example that demonstrates the importance of analyzing the individual energy components of the water life cycle. Although the development of the Blanes desalinization plant and the tertiary treatment facilities have the same objective of providing relief to the Tordera Aquifer, the energy required to deliver each supply source can produce varying results based on its vicinity to the end user. For example, the desalinated water must first be conveyed from the treatment plant in Blanes to the treatment plant in Tordera and then later conveyed the municipalities. Comparing the conveyance energy costs of this supply source versus the energy costs of tertiary treatment that occurs within the municipal boundaries becomes a valuable exercise. As shown in Figures 9 and 10, it would be less energy intensive in treatment and conveyance costs to augment supply through tertiary treatment than desalination. Looking specifically at Tossa de Mar, conveyance from the Blanes desalination plant to Tordera had an energy intensity value of 0.02 kWh/m3. Later, an additional 0.82 kWh/m3 was required for conveyance when the desalinated water was mixed with groundwater from the Tordera and sent to

Tossa de Mar. In comparison, conveyance of tertiary treated water within Tossa de Mar has a significantly lower energy intensity cost of 0.09 kWh/m3. This includes pumping the source to one public space at the top of a mountain overlooking the coast. When treatment costs are included, the total energy cost for tertiary treatment was 0.79 kWh/m3 versus 3.69 kWh/m3 for desalination.

OTHER SUSTAINABILITY CONSIDERATIONS

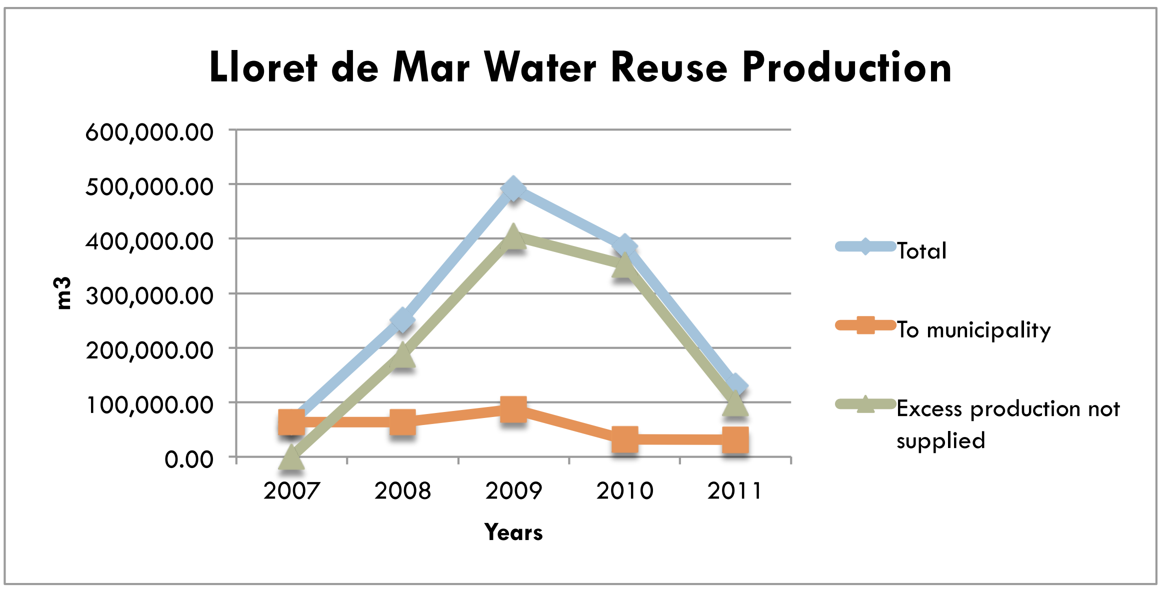
Although water reuse presents some advantages over desalinization, it is met with limitations as well. Water reuse is currently only for non-potable applications throughout the Costa Brava. This produces energy, infrastructural, and efficiency consideration. First, treating reclaimed water to potable standards requires more energy. Next, additional complementary infrastructure, such as a new pipeline network, is required for conveyance purposes. Last, depositories are needed to maximize the efficiency of the system. Securing the complementary infrastructure requires added funding sources. Budget constraints challenge the overall sustainability of this supply alternative.

Water reuse in the Costa Brava is currently only for non-potable applications. It does not meet drinking water standards. It is only used for distributive purposes, such as irrigation, street cleaning, and aquifer recharge. On the other hand, desalination provides an additional source of potable drinking water. In order to treat reclaimed water to potable quality reverse osmosis would need to be applied. This would increase the overall energy consumption value of the alternative source. As of now this paper cannot determine with confidence if treating wastewater through reverse osmosis increases energy consumption significantly. Table 2 presents varying rates suggesting a broad range of energy consumption values exist. The lower values originate from a potable tertiary treatment facility within California's Orange County Water District. The White Paper (2012) points out that energy consumption values for treatment vary depending on wastewater total dissolved solids.

Since water reuse in Tossa de Mar and Lloret de Mar are of no potable quality, the construction of a new network of pipelines is required . The non-potable source cannot mix with other potable sources of water during the conveyance process. Currently water reuse is only for municipal use. It has a very limited network in both Tossa de Mar and Lloret de Mar. It takes significant financial resources to connect a municipality completely to a dual distribution network. Therefore, demand for water reuse depends on the municipal network, not necessarily tertiary treatment production capacity. This has significant consequences for the overall sustainability of the supply source within a region such as the Costa Brava where a great portion of demand comes from within the second homeowner and tourism industry outside the center of town. Currently the water reuse supply network is confined to a very localized area surrounding the center of the municipalities. Extending the networks throughout the urbanizations would require significant funding. This is not expected to be budgeted for in the near future (pers. comm Jordi Couso). Considering lawn irrigation in second home tourist destination represents a significant portion of water use along the Mediterranean coast, this gap has significant consequences for achieving a reduction in potable supply and alleviating stress from the aquifer.

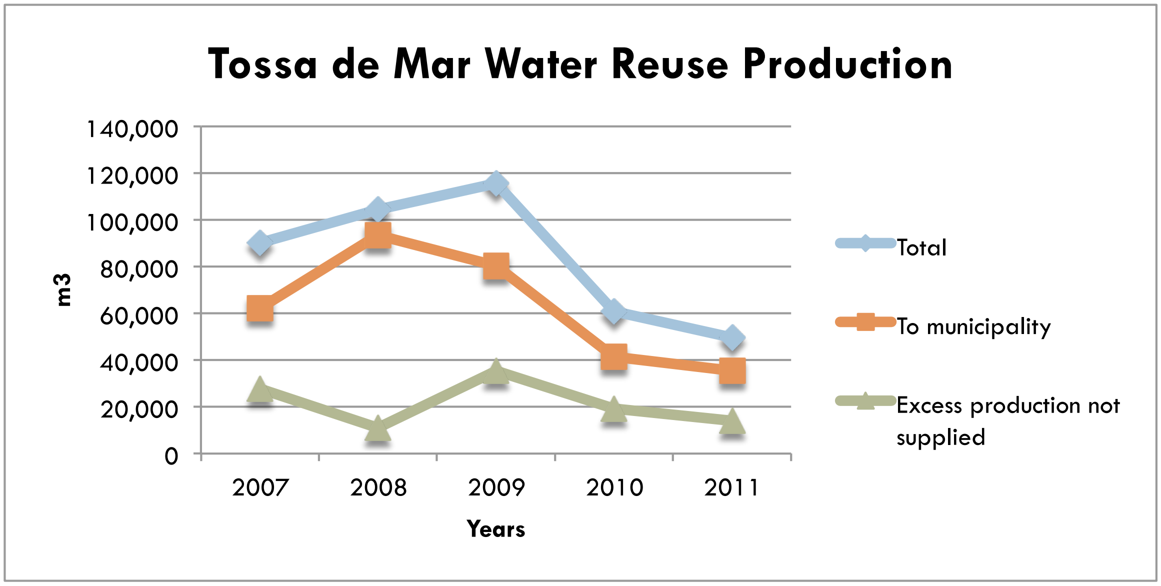
In addition to a new conveyance supply network, other important complementary infrastructure is required. Storage tanks are an important for the efficiency of the system. Unfortunately, they get excluded during budget cuts in times of economic crisis, resulting in a less efficient system. Comparing Figure 12 and Figure 13, it is evident that Tossa de Mar takes better advantage of the reuse supply than Lloret de Mar.

Figure 12
Total Water Reuse Production that Gets Distributed to Lloret de Mar or the Sea



(Source: Own elaboration with data from Consorci Costa Brava & Lloret de Mar Wastewater Treatment Facility)

Figure 13
Total Water Reuse Production that Gets Distributed to Tossa de Mar or the Sea



(Source: Own elaboration with data from Consorci Costa Brava & Tossa de Mar Wastewater Treatment Facility)

The majority of the wastewater that goes through tertiary treatment in Tossa de Mar is supplied to the municipality. On the contrary, current supply in Lloret de Mar is rather small compared to the size of the reclamation treatment facility. A majority of the tertiary treated water in Lloret de Mar went directly to the sea between the middle of 2008 until 2011. This is due to budget cuts resulting in construction delays of a larger depository. The absence of a larger storage tank results in the treatment facility producing tertiary treated water that is deposited directly into the sea. In 2011, the difference between what is deposited to the sea and what is deposited to the municipality minimizes. This is not because the depository was built. Rather, as seen on the graph, total production of reused water decreases dramatically. This was the treatment plant's reaction to optimize efficiency due to continued budget constraints. Total production was decreased to minimize overall supply that is dispersed directly into the sea (pers comm. Consorci Costa Brava, 2012). Last, while Tossa de Mar's distribution of tertiary treated water proves more efficient than Lloret de Mar, it is not free of limitations. According to a source at Tossa de Mar's Department of Environment, a secondary depository was not built up in the mountain due to budget cuts. This has resulted in insufficient pressure to turn on different valves simultaneously. If the municipality wants to irrigate one zone it must turn off the irrigation valves in a different zone (pers. comm. Jordi Couso, 2012).

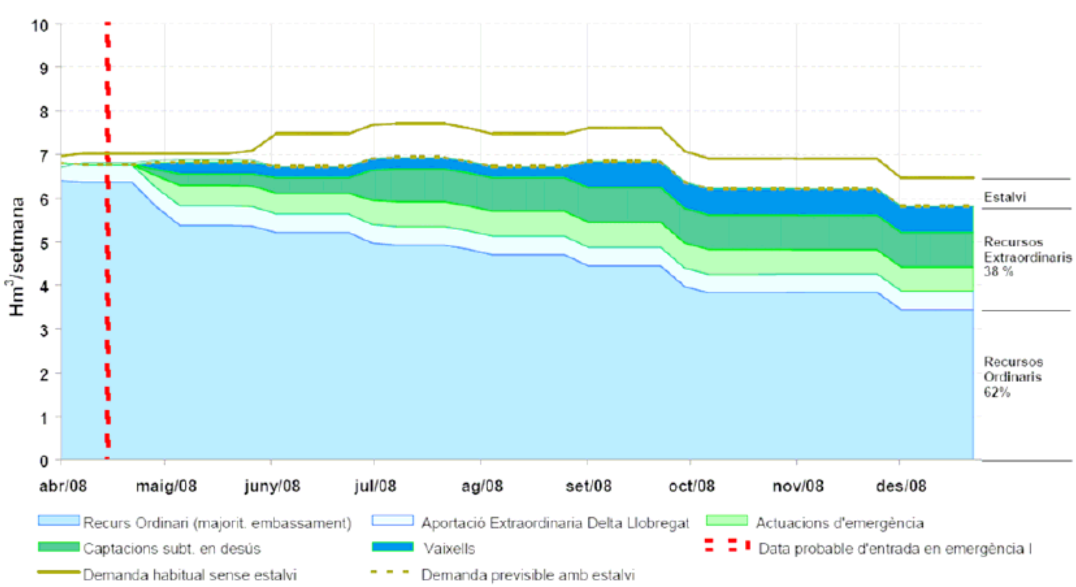
DISCUSSION

A severe drought took place throughout Catalunya from 2007 until spring of 2008. For one of the drought response mechanisms the Catalan Water Agency launched an extensive communications campaign. Within the metropolitan region of Barcelona, the campaign achieved a 20% savings in overall water consumption. Although significant resources were invested in the campaign, Figure 14 demonstrates that this savings was insufficient to meet demand. The dark solid line is where demand typically would lie. The dotted yellow line represents the reduction in demand after the aggressive conservation communications campaign. The supply between the dotted yellow line and the shaded light blue area represents the 38% increase in supply alternatives that authorities were forced to bring online to compensate for the supply deficit that year.

The 2007/2008 drought persuaded Catalan water authorities that an even more aggressive alternative supply strategy was needed to adequately respond to future drought years. The Pla de Gestió (2010) plan calls for the construction of more water reuse facilities and desalination plants. The Water Reuse program, PRAC, seeks to increase water reuse by 158 hm3 by 2015 and increase overall reuse supply by 25% by 2027 (Mas, 2011). Additionally, it calls for a 190 hm^3 increase in desalination by 2015. According to a civil servant at ACA, "as [Catalunya's] climate is highly variable, desalinated water use is restricted to drought situations. The main advantage is the ability to have a guaranteed source, not subject to the weather uncertainties. Moreover, it decreases territorial tensions often associated with interbasin transfers" (pers. comm ACA, 2013).

This paper outlines specific energy intensity and sustainability challenges water authorities face. These variables must be accounted for in all future water management plans. For example, water reuse has the potential to redirect pressure from local aquifers to tertiary wastewater treatment but particular limitations affect the sustainability of the supply mechanism. If conveyance and treatment values are compared, it is clear that further developing tertiary treatment facilities in Tossa de Mar and Lloret de Mar would be a superior option to desalinated water if an equivalent volume of drinking water could be replaced. Yet, keeping the limitations of tertiary supply is critical. Energy consumption of the supply source is superior to desalination as a non-potable source. However, applying reverse osmosis to bring the tertiary treated water to drinking water standards results in increasing energy consumption. Thus far it is unclear if it becomes comparable to desalination. If reality determines that treatment costs are comparable to the facility in Orange County California, then this paper recommends that developing a potable reuse facility would be more energy efficient and would take away the need to construct a new pipeline network. It is critical that the entire water supply life cycle is considered when influencing management decision-making.

Figure 14
2008 Water Demand and Drought Response for Barcelona Metropolitan Region



(Source: Pers. Comm ACA, 2013)

Need for Sectorial Integration

It is clear that water and energy are closely aligned. Water supply decisions come with attached energy consequences and vice versa. Currently, policies surrounding the water and energy sectors are enacted independent of each other. A push towards sectorial integration is required if authorities want to obtain sustainable water management.

Agenda 21 (1992) recognizes that water resource management is a multidimensional socio-political system. Under section 18.21 it claims that water related institutions require better land management integration to successfully implement demand-driven management strategies. While it is forward thinking in including cross-sectorial integration as part of the multidimensional component of sustainable water resource management, its prescription is incomplete. It is important that all water-related institutions go beyond land-use management and additionally incorporate energy use assessments. As different supply alternatives have varying energy intensity values, excluding energy consumption concerns denies important supply sustainability considerations. It is necessary that sectorial integration is clear and present in EU policies in reference to the "water-energy" nexus specifically.

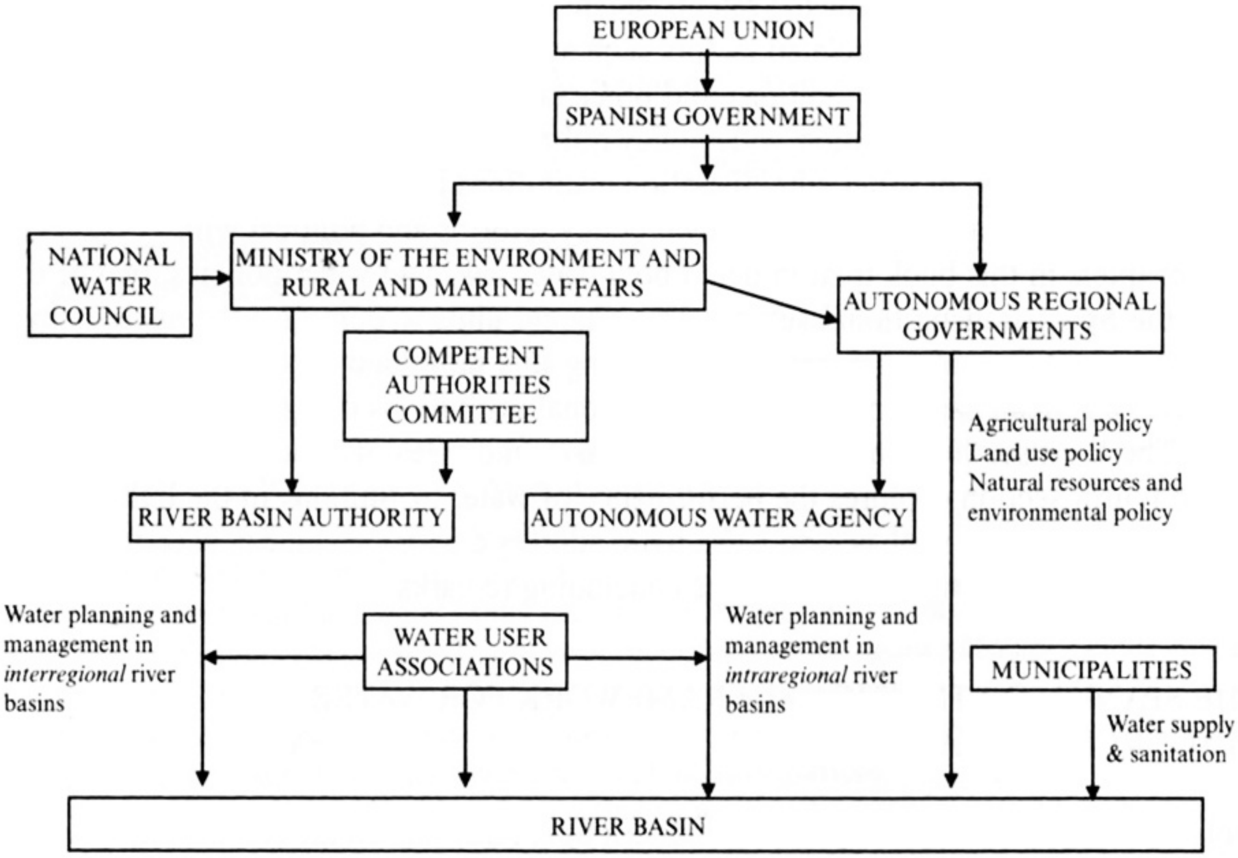
Currently, integration between European water and energy policies is weak. For instance, River Basin administrators, EU and national policy makers and other stakeholders claim there is a disconnection between the environmental objectives of the WFD and the EU green energy policy (Volkery et al., 2011). According to the European Commission's "General Union Environment Action Programme to 2020", the seventh priority listed under the policy prescription calls for improved environmental integration and policy coherence. Yet, the plan pushes both energy and water efficiency; however, it never mentions policy decision making processes that consider energy implications of particular water supply solutions and vice versa (EC 2012). Moreover, recent EU energy policies such as Directive 2005/89/ EC on security of electricity supply and Directive 2006/32/EC on end-use efficiency and energy services do not incorporate important water consumption factors (BioIs, 2009).

The European Innovation Partnership (2012) claims the greatest barriers to sufficiently integrating water and energy policy as follows:

- Lack of economic incentives for efficient technologies
- Water supply and wastewater systems do not have adequate low energy technologies available
- Water supply and wastewater are designed to operate with constant energy supply, whereas renewable energy sources provide variable supply loads.
- Wastewater recovery technologies are expensive and not fully available.

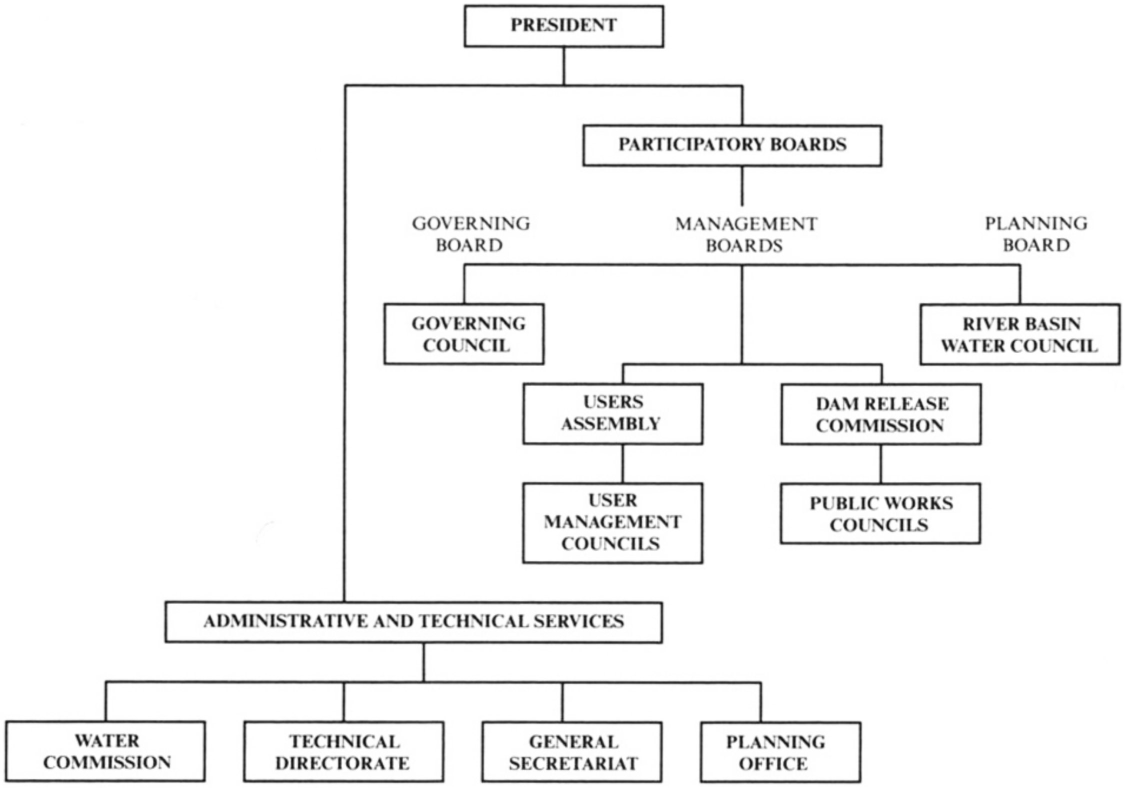
Although the factors laid out by the European Innovation Partnership surely are missing in the overall integration equation, this paper argues that the complexity of political institutional structure behind water supply and energy policy makes sectorial integration difficult. First, water resource management in particular is complex. The decision-making process is multidimensional in which supranational, national, and local policies influence the overall management scheme. Figure 15 and Figure 16 outline the various institutional levels that influence the water decision-making process in Spain.

Figure 15
Institutional Framework for Water Decision Making in Spain



(Source: Ortega & Hernández-Mora, 2010)

Figure 16
Organizational Structure of Spanish River Basin Authorities



(Source: Ortega & Hernández-Mora, 2010)

Policies passed within the entire institutional web have direct impacts on the local municipal supply. The increase in desalination plants and tertiary treatment facilities throughout Spain over the last two decades is a great case study to analyze how decisions throughout all institutional levels influence supply decisions at the local level. According to the OECD (2012), water and energy policy coherence is "systematic promotion of mutually reinforcing actions on the part of government. It underscores the fact that better water governance is critical to fostering inter-institutional mechanisms for horizontal co-ordination and encouraging synergies and complementarities between different policy fields related to water (p. 130). Currently, this notion of "horizontal co-ordination" between the water and energy sector is absent throughout the hierarchical water decision-making process. While water supply is typically managed at the municipal level within a decentralized government structure, energy policy and investments are controlled primarily at the national level (OECD, 2012). Spain's management of water and energy falls under this organizational structure.

Unlike a water supply source such as one river or aquifer that is typically exploited to provide water for a particular localized population, electricity conveyance relies on a mixture of different energy supply sources that produce electricity at various points around the country or neighboring countries.

Currently, representation from the energy sector only resides in one leg of the decision-making process. The National Water Council advises the Ministry of Environment on how all Nation water plans, agricultural, energy, industrial, or land use plans that significantly impact water resources (Ortega & Hernández-Mora 2010). The head of the Directorate General for Energy Policy and Mines, Ministry of Industry, Tourism and Commerce as well as a representative from the Spanish Association of Electrical Industry advise national water policy makers (OECD, 2012). According to a source at the Catalan Water Agency, these members of the energy sector sit within the council to ensure they their interests of electricity production are satisfied. They do not offer advice on how the water sector can incorporate better energy planning (pers. comm. ACA, 2013).

The energy sector's sole presence in the National Water Council throughout the water decision-making hierarchy is insufficient. It only deals with water for energy interests. The absence of integration at any other level means regional and local water authorities never come in contact with National energy planners and water supply decisions are made independent of the energy sector (pers. comm ACA, 2013). It is critical that energy consumption remains a parallel concern under each subset of the overall decision-making framework. The OECD (2009) lays out three important steps to achieving policy coherence. First, it is important that different components of government are able to come together to compare and debate any inconsistencies that may exist. Forums that bring different Ministries together are very beneficial. It is the recommendation of this paper that a member from the energy sector is incorporated into the institutional web at each level. It is important that energy policy does not remain solely a concern at the national level. It is critical that a member of the energy sector is employed at the regional autonomous and municipal levels. Within the River Basin authorities specifically, the energy sector should hold representation through both the participatory boards and technical services. Water and energy authorities at each level should meet once a year to discuss how policies at each institutional level are affecting water supply management decisions and their corresponding energy consumption components. Next, coordination committees placed at high levels of government must have arbitration power when debating policy implementation. So in the case of Spain, the sectorial liaison advising policy at each hierarchical tier requires a formative voice. They cannot simply act as an environmental figurehead. Instead, they need to be figures with authority in the political decision-making process. Last, the ability to monitor and report the impact development impacts produces important evidence ensuring coherence exists.

Potential Set Backs for Sectorial Integration

While sectorial integration is the only true means to achieve sustainable water management, the complexity of the water-decision water making hierarchy in Spain threatens the functionality of the recommended system laid out above. According to the literature, water resource management in Spain is fragmented. Discontinuity between the regional authorities, River Basin authorities, and municipal supplies creates and inefficient organizational structure (Ruiz-Villaverde et al., 2013; Cabrera et al., 2010). The River Basin Authorities already lack of financial, technological, and staff resources and is weak enforcement regime. The shift from traditional water infrastructure development and technical based management to a holistic integrated ecosystem management scheme has been challenging for the Authority (Custodio et al., 2010; Ortega & Hernández-Mora, 2010). Therefore, this paper recognizes that sectorial integration will be challenging in an already broken political structure. Adding more layers into an already fragmented structure could further complicate the decision-making process.

Demand Management

While sectorial integration is a critical component towards sustainable water management, the politics behind natural resource management is not the only barrier that requires attention. Importantly, water authorities and the municipalities must encourage responsibility at the water users level. Climate change and recent economic crisis teaches the Costa Brava that although supply management is part of the equation, a planning shift is desirable. Coastal development and water resources management also need to focus on demand management strategies. Brooks (2007) claims that water demand management recognizes the importance of changing the behavior of the users rather than focusing only on technology that augments forms of supply. He recognizes that limiting demand is a policy initiative and a governance issue.

Neither Lloret de Mar nor Tossa de Mar have local incentive programs for water users to adapt water efficient technologies. Water conservation messaging is only an emergency response tool. It is not a consistent strategy within the local government that works to change the behavior of users over time. During the severe drought in 2007-2008, Lloret de Mar followed the Catalan government's massive conservation campaign by blasting savings messages throughout all local media sources. The target of the campaign was at the general public. It did not specifically work within the tourism sector nor encourage second homeowners with extensive lawns to reconsider irrigation patterns. While Lloret de Mar has followed the global push for sustainable resource use by implementing its own Local Agenda 21 master plan, water resource conservation is not one of the main focuses of the plan. While it does offer recommendations for the municipality to then transfer over to the tourism industry, the incentives for water conservation remain at the European Union level. The municipality only encourages hotels to look for the various certifications offered by the EU (pers comm. Ajuntament Lloret de Mar, 2013). Yet, these programs are only voluntary measures.

The severe drought from 2007-2008 demonstrates that focusing on conservation strategies alone is insufficient to meet demand during emergencies. However, this should not be an excuse for water authorities and municipalities to deny the importance of demand management strategies within the sustainable water resource realm. Water policy that favors modernized infrastructure at the expense of user level demand management strategies can produce negative consequences. For example, it takes the responsibility of sustainably managing natural resources away from the individual user. It allows business as usual development trends to continue without attaching the obvious environmental consequences of unsustainable resource use. This could have localized consequences. Figure 14 presented earlier in the paper demonstrates that a 20% consumption savings does not compensate for demand. It is important to recognize that this data represents metropolitan urban water use surrounding Barcelona. Examining the potential of savings at a much smaller scale such as Tossa de Mar and Lloret de Mar could potentially lead to different results. A source at the Catalan Water Agency claims that while aggressive education savings would most likely be insufficient to compensate for the overexploitation of the aquifer during peak season, greater savings ratios could result from hotels implementing stronger conservation policies and if second home owners switched landscaping practices year round (pers. comm. ACA, 2013). A report released by Natural Resources Defense Council (2009) highlights important methods that can contribute to the demand management process. For example, cultivating native plants that do not require excessive irrigation, installing low flow water efficient technologies, and implementing low impact development strategies can lower the water the user demands from the initial stage. These supply management options can specifically target the tourism sector and create a sense of responsibility for overexploitation of water resources. Further research is required to measure the significance of these savings initiatives along the Southern Costa Brava.

Conserving water at the user level not only takes pressure off the aquifer but it has positive energy conservation benefits as well. Aggressive conservation campaigns and retrofitting incentives not only use water more efficiently but it also comes with attached energy savings. Decrease in demand results in a decrease in energy needs for pumping, treating, and conveying water year round. In addition, reduced water consumption in the home results in electricity reduction used for heating. The end-user has proven the greatest energy consumer throughout the entire water supply cycle due to heating and cooling needs (Fleming et al., 2013; Olsson, 2012). Therefore, although reliable supply needs cannot be denied, conservation and demand-management strategies are relevant for the overall sustainability of the water supply source.

CONCLUSION

Southern Costa Brava's increase in population during the summer months has caused an overexploitation of local groundwater resources that puts pressure on the aquifer and results in salinization of the groundwater source. The need to meet growing demand produces a supply-oriented mentality. If aggressive conservation and education campaigns result in a 20% savings in water consumption; yet demand still exceeds sustainable supply, alternative measures will need to be adopted to ensure the health of aquifer. It is unrealistic to believe that the coastal tourist destinations will revert back to a level of growth seen half a century ago. This does not mean; however, that the sustainability of the available supply sources should not be critically analyzed. Lack of integration between the energy and water sector produces supply alternatives detached of energy consumption consequences. Ignoring energy costs of the supply sources compromises the sustainability of the overall supply. Increased energy consumption not only has repercussions for increasing risks of climate change but high energy costs can have detrimental effects to providing sufficient supply.

Water is not the only finite resource. It is critical that future water management strategies are not initiated at the expense of other natural resources. Ocean water may be a renewable resource but the current energy mix to comply with treatment is not. While total energy use of the water life cycle may be a small percentage overall energy production, these systems are neither stagnant nor in isolation of each other. It is critical to remain aware of future projections of water supply alternatives that could shift the current overall energy consumption. Between 2006 and 2011 global desalination production had increased from 25 million m3 to 72 million m^3 per day. By 2015 the projection stands at 100 million m^3. While water production only accounts for 5% of overall electricity consumption globally, an increasing adoption of energy intensive supply alternatives could bring this statistic towards an upward trend. In the United Kingdom electricity use within the water sector is predicted to increase more than 60% based on advance treatment technologies and increased users (Olsson, 2012). In Spain, the 2005 National Hydrological Plan under the A.G.U.A program promotes increased construction of desalinization and water reuse treatment facilities. Catalunya's regional water management plan follows similar trend. While these supply alternatives meet increasing demand for fresh water resources, they come attached with consequential energy costs. Although desalination has the potential to maintain healthy aquifer levels and avoid additional pipeline construction over hundreds of miles, it comes with very high energy costs and creates a greater demand for energy producing natural resources. It is important that detailed energy-for-water production data exists so that policy makers can integrate energy considerations at each institutional level throughout the entire water resource management hierarchy.

Although aggressive savings programs have proven insufficient to meet demand, authorities cannot dismiss the importance of promoting behavioral changes at the user level. These campaigns should not only be adopted during times of emergency. Demand management campaigns that target the greatest users of water in a localized context produce many potential benefits. It reduces the constant demand for expensive infrastructure expansion. In addition, reducing demand from local freshwater sources saves energy. Less energy is required to pump, treat, and convey the potable water source. Also, using less water in the home reduces overall hot water heating costs, simultaneously reducing energy demands. According to the European Commission, the new voluntary EU Ecolabel and Green Public Procurement program that requires that all devices to meet a particular water efficiency standards has both water and energy saving benefits. If consumers choose to replace showers and faucets in their homes with the new Ecolable devices, approximately 3.5% of total residential energy consumption and nearly 1% in total energy production will decrease throughout the EU (EC, 2012, p.673). Last, promoting water and energy conservation throughout and primarily tourism driven economy presents benefits beyond savings. It also creates a new image for the municipality that makes it more desirable for tourists who demand a more eco-friendly type of tourism.

REFERENCES

Agenda 21 Lloret de Mar. Lloret de Mar Town Council. Lloret de Mar, Girona.

Araus, J.L. (2004). The problems of sustainable water use in the Mediterranean and research requirements for agriculture, Annals of Applied Biology, 144, 259-272.

Arrojo Agudo, P. (2010). The End of Large-Scale Water Projects. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p. 209-218). Leiden: CRC Press.

Bellot, J., Bone, A, Peña, J, & Sánchez, J.R. (2007). Human Impacts on Land Cover and Water Balance in a Coastal Mediterranean County. Environmental Management. 39, 412-422

BIOIS (2009) Water Efficiency Standards. Final Report to DG ENV. BioIntelligence Services, Paris.

Bolin, B., Seetharam, M., & B. Pompeii (2010). Water resources, climate change and urban vulnerability: a case study of Phoenix, Arizona. Local Environment, 15(3): 261-279.

Breton, F. & Sauri-Pujol, D. (1997). Toward a redefinition of resources and hazards in coastal management: Examples from the lowland coastal areas of Catalonia, Spain. Coastal Management 25(4), 363-385

Brooks, D.B. (2006). An Operational Definition of Water Demand Management. International Journal of Water Resources Development 22(4), 521-528.

Brooks, D.B. Beyond Greater Efficiency: The Concept of Water Soft Paths. (2005). Canadian Water Resources Journal, 30(1), 83-92

Bureau of Reclamation (2006). All American Canal Lining Project. Washington, D.C., United States: U.S. Department of Interior.

Burger, J. & Gochfeld, M. (1998) The tragedy of the commons: 30 years later." Environment. 40(10), 4-27.

Custodio, E., Ramón Llamas, M., Hernández-Mora, N., Martínez-Cortina, L., Martínez-Santos, P. (2010). Issues Related to Intensive Groundwater Use. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p. 145-164). Leiden: CRC Press.

Cabrera, E., Cabrera Rochera, E. & Cobacho, R. (2010) Water Supply in Urban Areas. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p. 77-84). Leiden: CRC Press.

Chung, Eun-Sung, Won-Pyo Hong, Kil Seong Lee, and Steven J. Burian. (2011). Integrated Use of a Continuous Simulation Model and Multi-Attribute Decision-Making for Ranking Urban Watershed Management Alternatives. Water Resurce Management. 25, 641-659

Dept. de Medi Ambient I Habitatge. Agència Catalana de l'Aigua. Directiva Marc de l'Aigua a Catalunya (2005) Retrieved from: http://aca-web.gencat.cat/aca/appmanager/aca/aca?_nfpb=true&_pageLabel=P1205854461208200574455

Dietz, T., Ostrim, E., & Stern, P.C. (2003) The struggle to govern the commons." Science. 302, 1907-1912

Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000: establishing a framework for Community action in the field of water policy (2000). European Parliament and Council. Brussels.

Dolz, J. & Armengol, J (2011). Els recursos hídrics a catalunya dades i conceptes basics", Cambra de Comerç, Indústria i Navegació de Barcelona. Retrived from: http://www.cambrabcn.org/c/document_library/get_file?uuid=2024f010-eccb-4c79-a8a4-f35f59e7ea8c&groupId=1533402

EC (2011b) Report from the Commission to the European Parliament and the Council. Third follow up report to the Communication on water scarcity and draughts in the European Union COM2007(414). COM(2011)133. 21 March 2011. European Commission. Brussels.

EC (2012) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A Blueprint to Safeguard Europe's Water Resources. COM2012(673). 14 November 2012. European Commission. Brussels.

EC (2012) Proposal for a Decision of the European Parliament and of the Council on a General Union Environme Action Programme to 2020. Living Well, within the Limits of our Plant. COM2012(710). 29 November 2012. European Commission. Brussels.

Elliott R.N. (2005). Roadmap to energy in the water and wastewater industry. Rep. IE054, Am. Counc.Energy Effic. Econ., Washington, DC

Embid, A. (2002). The evolution of water law and policy in spain. International Journal of Water Resources Development, 18(2), 261-283. doi:10.1080/07900620220135094

Embid, A. (2003). The transfer from the ebro basin to the mediterranean basins as a decision of the 2001 national hydrological plan: The main problems posed. International Journal of Water Resources Development, 19(3), 399-411. doi:10.1080/0790062032000122989

Essex, Stephen, Martin, Kent, and Rewi, Newnham (2004). Tourism Development in Mallorca: Is Water Supply a Constraint? Journal of Sustainable Tourism 12(1), 4-28.

Gamero, D. P. (2012). From private initiative to public intervention in spanish water management: The case of the muga and fluvia rivers (1850-1930). Journal of Historical Geography, 38(3), 220. doi:10.1016/j.jhg.2012.03.002

Getches, D. (2003). Spain's ebro river transfers: Test case for water policy in the european union. International Journal of Water Resources Development, 19(3), 501-512. doi:10.1080/0790062032000122925

Gleick, P. H. (2003). Global Freshwater Resources: Soft-Path Solutions for the21st Century. Science, 302(5650), 1524-1528.

Hardy, L., Garrido, A., & Juana, L. (2012). Evaluation of Spain's Water-Energy Nexus. International Journal of Water Resources Development, 28(1), 151-170. doi: 10.1080/07900627.2012.642240

Hawkins, Christopher V.. and XiaoHu Wang. (2012). Sustainable Development Governance: Citizen Participation and Support Networks in Local Sustainability Initiatives.Public Works Management & Policy. 17(1), 7-29.

Hennessy, M. (2004). Colorado River Water Rights: Property Rights in Transition. University of Chicago Law Review 71(4): 1661-1688.

Hussey, K., & Pittock, J. (2012). The Energy-Water Nexus: Managing the Links between Energy and Water for a Sustainable Future, Editorial, Ecology & Society, 392-400.

Jepson, E. J. (2004). Human Nature and Sustainable Development: A Strategic Challenge for Planners. Planning Literature. 19(3), 3-15.

Jenkins, D. (2009). When The Well's Dry': Water and the Promise of Sustainability in the American Southwest. Environment and History 15, 441–462.

Jiménez Torrecilla, N., & Martínez-Gil, J. (2005). The New Culture of Water in Spain. Un Philosophy Towards Sustainable Development. European Water Association. 1-20.

Kirsch, R. (2009). Groundwater quality-saltwater intrusion. In Kirsch, R. (Ed). Groundwater Geophysics: A tool for Hydrogeology, (p. 423-438). Berlin: Springer.

Khublaryan, M.G., Frolov, A.P., Yushmanov, I.O. (2008). Seawater Intrusion into Coastal Aquifers. Water Resources, 35(3), 274–286.

La Energia en España. (2009). Ministerio de Industria, Turismo, y Comercio. Madrid

Martínez-Cortina, L. (2010). Physical and hydrological characteristics. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p.11-20). Leiden: CRC Press.

Mas i Lloret, O. (2011). *Crònica de l'aigua a la Costa Brava*. R. Pinyol i Balasch (Ed.). Girona, Spain: Clipmèdia Edicions.

McMahon, J.E. & Price, S.K. (2011). Water and Energy Interactions," Annual Rev. Environ. Resources, 36, 163–91.

Menéndez Prieto, M. (2010). Facing the Challenges of Implementing the European Water Directive in Spain. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p. 175-184). Leiden: CRC Press.

Meerganz von Medeazza, G. L. (2005). "Direct" and socially-induced environmental Impacts of desalination. Desalination, 185(1), 57-70.

Molina, V. G., & Casañas, A. (2010). Reverse osmosis, a key technology in combating water scarcity in spain. Desalination, 250(3), 950-955.

Montoya-Hidalgo, J.M. (2007). Instruments of Public Participation in Aragon Water Policy: The Aragon Water Commission. International Journal of Water Resources Development, 23(1), 41-50

Morris, A. & Dickinson, G. (1987) "Tourist Development in Spain: Growth versus Conservation on the Costa Brava." Geography, 72(1), 16-25.

Nat. Resour. Def. Counc. (NRDC). Water Efficiency Saves Energy: Reducing Global Warming Pollution Through Water Use Strategies. NRDC, Los Angeles, CA. (2009) Retrieved from: http://www.nrdc.org/water/files/energywater.pdf

OECD (2009). "Building Blocks for Policy Coherence For Development." OECD Publishing, Paris.

OECD (2012), "Meeting the water coherence challenge", in OECD, Meeting the Water Reform Challenge, OECD Publishing, Paris. doi: 10.1787/9789264170001-7-en

Olsson, G. (2012). Water and Energy: Threats and Opportunities. London, UK: WA Publishing.

Pinilla, V. (2006). The Development of Irrigated Agriculture in Twentieth-Century Spain: A Case Study of the Ebro. The Agricultural History Review, 54(1) 122-141

Pla de gestió del districte de conca fluvial de Catalunya. (2010). Agencia Catalana de L'Aiguas. Barcelona.

Plappally, A. K., & Lienhard V, J. H. (2012). Energy requirements for water production, treatment, end use, reclamation, and disposal. Renewable & Sustainable Energy Reviews, 16(7), 4818-4848. doi: 10.1016/j.rser.2012.05.022

Ruiz-Villaverde, A., Garcia-Rubio, M., & Gonzalez-Gomez, F. (2010). Analysis of urban water management in historical perspective: Evidence for the spanish case. International Journal of Water Resources Development, 26(4), 653-674. doi:10.1080/07900627.2010.519497

Sala, L. & Serra, M. (2004). Towards sustainability in water recycling. Water Science and Technology 50(2), 1–7.

Sardá, R., Mora, J. & Ávila, C. La Gestión Integrada de zonas costeras como instrumento dinamizador de la industria turística en la Costa Brava. Girona, 2004. CSIC (www.esade.es)

Schmidt, G. & DeStefano, L. (2010) Major Processes Degrading Freshawater Resources and Ecosystems. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p. 29-37). Leiden: CRC Press.

Schroeder, E., Tchobanoglous, G., Leverenz, H. L., & Asano, T. (2012). Direct Potable Reuse: Benefits for Public Water Supplies, Agriculture, the Environment, and Energy Conservation (pp. 1-12). Davis, California: National Water Research Institute.

Saurí, D., & Del Moral, L. (2001). Recent developments in spanish water policy. alternatives and conflicts at the end of the hydraulic age. Geoforum, 32(3), 351-362. doi:10.1016/S0016-7185(00)00048-8

Stetter, S., Herschinger, E., Teichler, T., Albert, M. (2011). Conflicts about water: Securitizations in a global context Cooperation and Conflict, 46, 441-459

Stoeglehner, G., Edwards, P., Daniels, P., & Narodoslawsky, M. (2011). The water supply footprint (WSF): a strategic planning tool for sustainable regional and local water supplies. Cleaner Production. 19, 1677-1686.

Stonich, S.C. (1998). Political Ecology of Tourism. Annals of Tourism Research. 25(1) 25-54.

Strategic Implementation Plan. (2012) (pp. 1-22). Brussels: European Innovation Partnership.

Tàbara, J. D., & Ilhan, A. (2008). Culture as trigger for sustainability transition in the water domain: The case of the spanish water policy and the ebro river basin. Regional Environmental Change, 8(2), 59-71. doi:10.1007/s10113-007-0043-3

Varela Ortega, C. & Hernández-Mora, N. (2010) Institutions and Institutional Reform in the Spanish Water Sector: A Historical Perspective. In A. Garrido & M.Ramón Llamas (Eds.), Water Policy in Spain (p. 117-130). Leiden: CRC Press.

Volkery, A., Geeraerts, K., & Farmer, A. (2011). European Commission – General Directorate Environment Support to Fitness Check Water Policy. Belgium: Deloitte Consulting Institute for European Environmental Policy

Ward, E (2001). Geo-Environmental Disconnection and the Colorado River Delta: Technology, Culture, and the Political Ecology of Paradise. Environment and History 7(2): 219-246

"Water Reuse Project of Tossa de Mar, Consorci of Costa Brava." 8th IWA International Conference on Water Reclamation and Reuse. 26-29 September 2011, Barcelona. Ed. Buixeda, M., Mujeriego,R., Sala,L. Retrieved from: http://www.waterbcn2011.org/download/Water%20Reuse%20Project%20of%20Tossa%20de%20Mar.pdf

"Water Reuse Project of Lloret de Mar, Consorci of Costa Brava." 8th IWA International Conference on Water Reclamation and Reuse. 26-29 September 2011, Barcelona. Ed. Cousco, J., Mujeriego,R., Sala,L. Retrieved from: http://www.ccbgi.org/docs/iwa_bcn_2011/Technical%20visit%20-%20Water%20Reuse%20Project%20of%20Lloret%20de%20Mar.pdf