# Critical review of desalination in Spain: a resource for the future?

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**Abstract**

There have been significant territorial changes in the Spanish Mediterranean in the last few decades because of the important growth of the residential tourism functions. The Spanish National Hydrological Plan (2001) and, to a greater extent, the Action for Management and Use of Water Programme (2004) advocated large-scale desalination of seawater to guarantee a supply for urban, tourism, and even future agricultural demands. The paralysis of urban development planning caused by the financial crisis (2007/08), together with the downward trend in the consumption of drinking water in the last decade, highlighted a capacity to produce desalinated water that was far superior to actual needs. This study reviews the current context in which desalinated water is produced in Spain, weighs up the advantages and disadvantages of this method, and considers the potential role that this non-conventional source of water could play as a strategic resource in the future. The main findings of the study are that desalination is not a panacea; rather, it should be considered in terms of technological parameters tailored to the circumstances of each geographical and socioeconomic environment.

**Keywords** *water resources; desalination; urban growth; drought; water demand; Spain*



## Introduction

This study was prompted by a heated debate in Spain about desalination as the solution to cyclical and structural drought problems affecting sections of the Spanish Mediterranean coastline. This controversy has gone beyond purely technical considerations to pervade the political arena; it has created a wide division between the proponents of desalination and the advocates of water transfers, although not as the preferred but rather as the only solution to the water demand problems (March, 2015; McEvoy, 2014).

Internationally, there is marked political controversy over the production of desalinated water and no technical, economic, or environmental balance informing how this non-conventional source can help to deal with periods of drought, or with possible increases in the demand for water. In Latin America, conflicts over water megaprojects are common (Boelens *et al.*, 2012; Latta & Gómez, 2014). In other regions, such as in Asia, water resource megaprojects, including dams and water transfers, have also produced social opposition (Nüsser, 2013). In the USA, the government of California, for example, has rejected desalination, because it secures inexpensive water from the Colorado River and from aquifers, and there are large state subsidies for water. However, private desalination plants have been opened all over the state because droughts and the irrational exploitation of groundwater resources have affected water supply. Elsewhere, desalinated water processes are becoming increasingly competitive,

Table 1 Main desalination plants and capacity production ($hm^3$ $year^{-1}$) in the Spanish Mediterranean Q5

| Big plants (>25 × $10^6$ $m^3$ $year^{-1}$) | Medium plants (25–10 × $10^6$ $m^3$ $year^{-1}$) | Small plants (9.9–5 × $10^6$ $m^3$ $year^{-1}$) |
|---|---|---|
| Torrevieja (80 × $10^6$ $m^3$ $year^{-1}$) (Valencia) | Escombreras (23 × $10^6$ $m^3$/year) (Murcia) | Xàvia ([illegible] $10^6$ $m^3$ $year^{-1}$) (Valencia) |
| Águilas (70 × $10^6$ $m^3$ $year^{-1}$) (Murcia) | Costa del Sol (21 × $10^6$ $m^3$ $year^{-1}$) (Andalusia) | Dénia (8.3 × $10^6$ $m^3$ $year^{-1}$) (Valencia) |
| El Prat (60 × $10^6$ $m^3$ $year^{-1}$) (Catalonia) | Marbella (20 × $10^6$ $m^3$ $year^{-1}$) (Andalusia) | Sagunto (8 × $10^6$ $m^3$ $year^{-1}$) (Valencia) |
| El Atabal (60 × $10^6$ $m^3$ $year^{-1}$) (Andalusia) | Mut × amel ([illegible] × $10^6$ $m^3$ $year^{-1}$) (Valencia) | El Mojón (6 × $10^6$ $m^3$ $year^{-1}$) (Murcia) |
| Valdelentisco (50 × $10^6$ $m^3$ $year^{-1}$) (Murcia) | Oropesa (18 × $10^6$ $m^3$ $year^{-1}$) (Valencia) | Sant Antoni (6 × $10^6$ $m^3$ $year^{-1}$) (Majorca) |
| Alicante I and II (48 × $10^6$ $m^3$ $year^{-1}$) (Valencia) | Bajo Almanzora (15 × $10^6$ $m^3$ $year^{-1}$) (Andalusia) | Gandía I (5.8 $10^6$ $m^3$ $year^{-1}$) (Valencia) |
| San Pedro del Pinatar I and II (48 × $10^6$ $m^3$ $year^{-1}$) (Murcia) | Moncófar (11 × $10^6$ $m^3$ $year^{-1}$) (Valencia) | Gandía II (5.8 × $10^6$ $m^3$ $year^{-1}$) (Valencia) |
| Carboneras (44 × $10^6$ $m^3$ $year^{-1}$) (Andalusia) | Tordera (10 × $10^6$ $m^3$ $year^{-1}$) (Catalonia) | Bahía d'Alcudia (5 × $10^6$ $m^3$ $year^{-1}$) (Majorca) |
| Campo de Dalías (36 $hm^3$ $year^{-1}$) (Andalusia) | Virgen de los Milagros (10 × $10^6$ $m^3$ $year^{-1}$) (Murcia) | Andrat × ([illegible] $10^6$ $m^3$ $year^{-1}$) (Majorca) |
| Bahía de Palma (25 × $10^6$ $m^3$ $year^{-1}$) (Majorca) | | Calpe (5 × $10^6$ $m^3$ $year^{-1}$) (Valencia) |



consume less energy, and are less harmful to the environment.

The panacea of desalination is articulated through two themes. Firstly, the sea offers a solution to the problems of contested traditional terrestrial supply and, secondly, the lure of 'new' water provides a technological solution to the problem of an inadequate, allegedly insufficient or unreliable supply (Swyngedouw, 2007; Swyngedouw & Williams, 2016). In the context of repeated droughts, which are likely to increase in the future because of climate change, and the economic, social, and environmental costs of conventional, large-scale water supply options such as dams and inter-basin water transfers, desalination appears to be a type of 'cornucopia' that in principle can solve future water needs of urban expansion in Spain.

As Swyngedouw and Williams state (2016, p.55), describing desalination as a panacea does not infer that it is uncontested and unproblematic. A re-examination of the situation in recent years has highlighted the absurdity of such entrenched positions that focus solely on the supply of water rather than on the proper management of resources and demand. It would appear that a purely technical and objective review is required of the studies and data for and against desalination, and this is the main goal of this study. Although it is largely based on data about Spain, it discusses the advantages and disadvantages of desalinated water applicable to similar geographic and socioeconomic contexts such as in the Mediterranean or the driest areas of USA or Australia (Baldwin & Uhlmann, 2010; Martínez-Fernández, 2009).

A comprehensive analysis of the literature on desalination worldwide was conducted to determine the advantages and disadvantages of this method to obtain drinking water, as identified by leading authors. The literature considered has ranged from purely technical studies to others that explore social, ecological, and economic issues. The sources of information used for our paper are published literature on the subject, and the critical reading of a number of official reports. The viability reports of the desalination plants on the Spanish Mediterranean coast built by the public company Acuamed within the Action for Management and Use of Water (AGUA) Programme have been analysed. Since 2005, these reports have been required by the Spanish Water Law (Art. 46) for all hydraulic infrastructure of general interest, and they must include a specific study on cost recovery (see the *Spanish Ministry of Agriculture, Food and the Environment,* 2013 and Acuamed, 2013). Q6 The majority of these reports were finished between 2006 and 2007, and they contain old information, which were updated with data obtained during 2015–16 in various meetings held with the technical managers of Acuamed.

Secondly, detailed information has been used about the running costs, energy consumption and production data of the four large plants built by the *Mancomunidad de los Canales del Taibilla*. This information was obtained in various meetings held with the company's technical managers during 2016, and it has been complemented by data supplied by the heads of the desalination plants of the Canal de Alicante I and II. The study also contains data supplied by the Pricing Commission of the Government of Valencia, about the operating costs of 25 small desalination plants run by private urban and tourism drinking water companies. These plants, built on the Valencian coast, treat brackish water that is collected in salinized coastal aquifers (Abad & Moreno, 2015). In addition, we obtained data from the *Sindicato Central de Regantes del Acueducto Tajo-Segura, Junta Central de Usuarios del Vinalopó-l'Alacantí* and *Consorcio de Aguas de la Marina Baja*.

Thirdly, current press reports were analysed to determine the extent to which political and social controversy regarding drinking water extraction methods has become a battle between sworn enemies, and this is demonstrated by the aforementioned political struggle, and also by regional conflicts.

The paper is organised as follows. In the section on , following, we analyse desalinated water production capacity in Spain and worldwide. In section, a desalination debate is presented. Finally, in the and , critical assessments are made of the context in which desalination is debated in the study area and of the possible implications of the lessons learned in this case for other areas interested in developing desalination projects.

## Desalinated water production capacity in Spain and worldwide

Currently, according to the International Desalination Association (2016), around 300 million people worldwide are drinking desalinated water. Furthermore, given the fact that population figures could reach 9,000 million by 2030 and that much of this population will be living in coastal areas, the production of desalinated water could rise from 140 to 160 million cubic metres per day to satisfy the increased demand for water. In over 150 countries, use is made of desalination to augment available water resources (Olcina & Moltó, 2010) and the use of desalinated water is widespread across Saudi Arabia, the United Arab Emirates, and the USA.

According to the latest data from the International Desalination Association (2016), the desalination capacity of public water treatment plants (18,426) is 86.8 × $10^6$ $m^3$ $day^{-1}$ (31,682 × $10^6$ $m^3$ $year^{-1}$). According to the World Health Organisation (2011), *Desalination is increasingly being used to provide drinking water under conditions of freshwater scarcity*. Such scarcity is expected to become more pronounced as populations grow, and urban development and climate change continue (March *et al.*, 2014). Desalination has become an increasingly attractive technological and social solution to cope with the pressures of urban development, climate change, and domestic water consumption. In a context of more frequent and prolonged drought, it is quite likely that water consumption will increase in the future because of climate change.

The first desalination plant in Spain (and Europe) was built in 1965 on Lanzarote Island (Canary Islands), and the technology used was solar evaporation, a technique that is rarely used today because it has been replaced by reverse osmosis. The first reverse osmosis desalination plant was built in 1970 on Las Palmas Island (Canary Islands), and it is currently run by Emalsa. Peninsular Spain followed suit in 1993 with the construction of the Cabo de Gata reverse osmosis desalination plant in the province of Almeria (southeast Spain), prompted by the drought of 1990–95, which highlighted the severe urban water supply problems in the regions of Andalusia, Murcia, and Valencia. Nowadays, the most important desalination plant in Spain and Europe is located in Torrevieja in the province of Alicante, in the Region of Valencia (Figure 1). Construction F1 began in 2006 and was completed in 2010, although the plant did not go into operation until August 2015. With a production capacity of 80 × $10^6$ $m^3$ $year^{-1}$ until a few years ago, the plant was the second largest in the world. Another important desalination plant in terms of the production capacity and the population supplied is the plant of El Prat (60 × $10^6$ $m^3$ $year^{-1}$) located in the metropolitan area of Barcelona, which is one of the most heavily populated areas in Spain (3,239,337 inhabitants) (INE, 2012).

The greatest investment in desalination in Spain was the AGUA Programme (2004) (*Royal Decree Law 2/2004*, 19 June). This programme started with the assent to power of the *Partido Socialista* in the elections of March 2004, because a new water policy in the Mediterranean basins was projected to benefit from the Ebro Transfer (National Hydrological Plan, Law 10/2011). The total

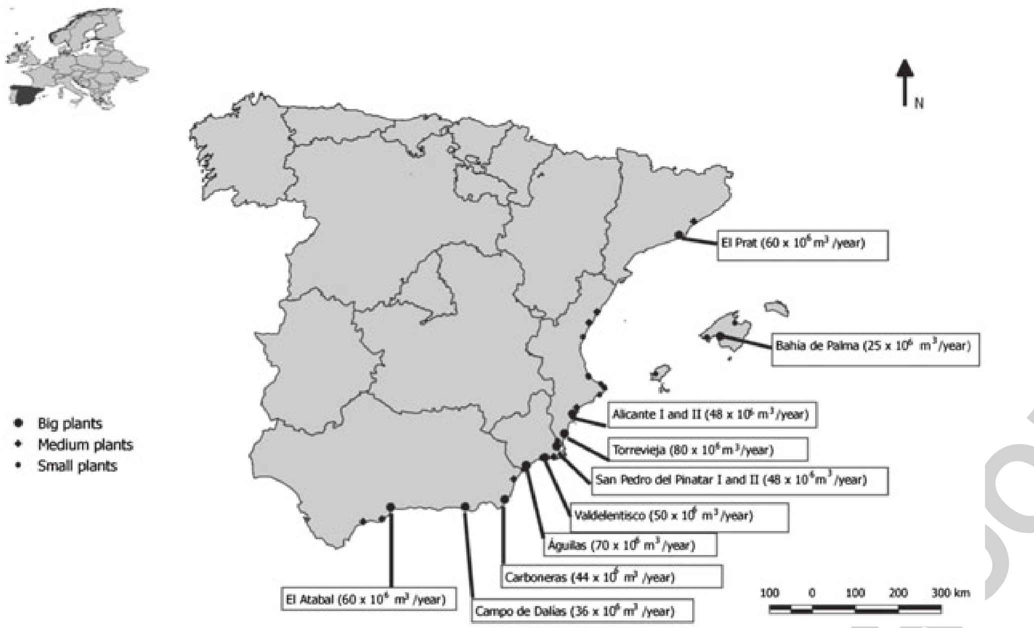


Figure 1 Main desalination plants in the Spanish Mediterranean
Source: elaborated by the authors

cost in relation to desalination was a state investment of close to €1,100 million (€200 from the EU ERDF and Cohesion Funds). The remaining funds were mainly obtained from internal resources and loans from the public company Acuamed. One of the goals was to replace the Ebro Transfer (1,050 × $10^6$ $m^3$ $year^{-1}$) with desalination in the east and southeast of Spain. According to the latest studies and official statistics, in Spain, the total water consumed is 142,548 × $10^6$ $m^3$ $year^{-1}$ approximately, representing surface water (111,000 × $10^6$ $m^3$, or 77%), groundwater (29,900 × $10^6$ $m^3$, or 21%), desalination (1,100 × $10^6$ $m^3$ of capacity, or 0.7%), and reclaimed water (548 × $10^6$ $m^3$, or 0.38%, but 11% of total purified water).

During the last housing bubble between the mid-1990s and 2000s, Spain witnessed a spectacular increase in the construction of residential units, whose growth continued unabated until the bubble burst and the economic crisis erupted in 2007/08 (Burriel, 2009; Morote & Hernández, 2016a). In southeast Spain, where the majority of desalination plants have been built, and where urban and tourism development has been the most intensive, the issue of desalinated water has become a source of controversy and debate in the regions of Valencia and Murcia. In addition, increases in urban sprawl are characterised by the presence of gardens and pools, leading to an increase in water demand (Morote, 2016; Morote-Seguido & Hernández-Hernández, 2016b; Morote *et al*., 2016b).

## The desalination debate

### *The socio-environmental implications of desalination*

In Spain, desalination has sparked intense debate, and caused controversy and conflicting opinions, especially in Valencia and Murcia in southeast Spain, which benefitted from the Ebro water transfer scheme proposed in the Spanish Hydrological Plan (2004). Traditionally, Spanish water policies were based on the construction of large infrastructures such as dams, water transfer schemes, and more recently, desalination plants, which were intended to increase the supply of resources and solve problems caused by increased demand and the risk of drought in the most vulnerable regions (Saurí & Del Moral, 2001). Therefore, desalination is a new and decisive element in hydrological planning, which provides a typical hydraulic solution to the problem of supplying water in a context of continuous urban expansion on the Spanish Mediterranean coast, and thus, as indicated by March *et al*. (2014, p.2642), *mitigating any possible constraints on this growth*. Proponents of desalination in Spain argue that this could be the solution to the problems of supplying water on the Mediterranean coast, and perhaps the key to solving water supply problems to new urban developments (Arrojo, 2004). It is also a resource immune to weather conditions and variations in availability that affect inland water resources ( Feiltelson & Rosenthal, 2012; Martínez-Fernández, 2006), and it could end the political and inter-regional conflicts caused by water transfer between regions (Saurí, 2003).

Other authors, however, have warned of the risks posed by desalination, as it involves a series of contradictions and problems (Swyngedouw & Williams, 2016). Firstly, desalination can have a negative effect on the environment, especially on marine ecosystems, as a result of brine discharge (Bernat *et al.*, 2010; Sadhwani *et al.*, 2005). Secondly, and most importantly, desalination is energy intensive and it produces high $CO_2$ emissions and brine discharge into the sea (Bates *et al.*, 2008; Meerganz von Medeazza, 2004), although this latter problem has been mitigated with the development of new dilution techniques that help prevent damage to the *Posidonia oceanica* meadows (Sánchez-Lizaso *et al.*, 2008). $CO_2$ emissions linked to electricity consumption might be partially offset because the use of desalinated water could avert other energy costs throughout the plant's life cycle (Baltanás, 2013).

Furthermore, desalination is rejected by the general public on the Spanish Mediterranean coast. According to surveys conducted by March *et al.* (2015) in coastal areas of Alicante (southeast Spain), desalination is not strongly supported by the general population. The most popular alternative mentioned by respondents to increase water resources in this region was the use of rain water, followed by an increase in water supplied from the Tagus-Segura transfer, the execution of the Ebro transfer, the reuse of treated wastewater, and in last place, increased desalination production capacity.

### *The energy and economic implications of desalination*

The link between water and energy becomes particularly evident with desalination because of the large amount of electricity required to desalinate water (Gober, 2010; Siddiqui & Diaz, 2011). Since the 1970s, the average cost of desalinated water production has fallen, as has energy consumption. Furthermore, energy costs have fallen, and so have those associated with membrane replacement and maintenance. Besides, there has been a progressive reduction in investment costs per installed unit and the quest for greater economies of scale has resulted in lower loan repayments.

In Spain, in a study on the evolution of energy consumption, according to Del Villar (2014), energy fell from 22 kWh $m^{-3}$ in 1970 to 3.3 kWh $m^{-3}$ in 2003, and he calculated that the repair and maintenance costs accounted for 88 per cent of the total, 56.4 per cent of which was energy consumption and 31.6 per cent maintenance and replacement. As Prats and Melgarejo (2006) reported, energy consumption in brackish water treatment plants ranges between 0.7 and 2.5 kWh $m^{-3}$ depending on the water salinity and the type of desalination process, with medium or small plants that produce between 10,000 and 1,000 $m^3$ $day^{-1}$ typically consuming between 0.9 and 1.1 kWh $m^{-3}$. According to reports issued by the Institute for Foreign Trade (2007), energy consumption in 2007 was 3 kWh $m^{-3}$, with the two main costs being divided into 43 per cent for energy and 37 per cent for loan repayments. As the Spanish Institute for Energy Saving and Diversification (2010) reported, the average energy consumed to desalinate water in Spain ranges from 3.5 kWh $m^{-3}$ (under ideal conditions) to 5 kWh $m^{-3}$ (in modern reverse osmosis plants), and this is even more in other plants.

According to data presented by Professor Daniel Prats at the 'Water and Sustainable Development Seminar' held in 2015 at the University of Alicante (Region of Valencia), the energy consumption of desalinated water stood at 20 kWh $m^{-3}$ in 1970, a figure that had dropped to 3 kWh $m^{-3}$ by 2014, and 1.5 kWh $m^{-3}$ in the case of brackish water. Pursuant to the data obtained during our interviews, in 2016, the energy consumption in the Torrevieja plant (built by Acuamed) is 2.9 kWh $m^{-3}$. Moreover, thanks to a deal with the energy company (the same one that manages the plant—Acciona), Acciona pays €0.07/kWh, which is cheaper than the price paid by other customers such as the *Junta Central de Usuarios del Vinalopó-l'Alacantí* (€0.09 $kWh^{-1}$) or the *Consorcio de Aguas de la Marina Baja* (€0.11 $kWh^{-1}$). In comparison with Spanish water transfers, the average energy consumption of water is 1.11 kWh $m^{-3}$ for the Tagus-Segura scheme (López-Milla, 2009), 2.5 kWh $m^{-3}$ for the Júcar-Vinalopó transfer, and 2.7 kWh $m^{-3}$ for the Ebro transfer (Rodenas & Guillamón, 2005).

It should also be pointed out that despite the liberalisation of the electricity market, businesses have seen their energy bills rise by more than 70 per cent since 2007, reaching an average of

€0.22 kWh$^{-1}$ (UNESA, 2015). To a large extent, the final cost of desalinated water is determined by the energy consumption and the price of electricity. Over the past decade, most of the plants built by Acuamed were supported by economic feasibility reports that showed electricity prices being well below their current levels (Acuamed being the main entity of the Spanish Ministry of Agriculture, Food and Environment that is responsible for the development of the Mediterranean River Basin Development Programme). Moreover, these costs were underestimated because they did not provide for the impact of liberalising the electricity market in Spain in 2008 at the request of the European Union, which entailed the suppression of protected rates. Liberalisation has led to a 600 per cent increase in the standing charge, which now represents 33 per cent of the total electricity bill, while the current cost of electricity during peak, standard, and off-peak times has doubled and tripled compared with prices in 2008 (Rico, 2010) (Figure 2).

With regard to economic costs, Del Villar (2014) reported that the price per cubic metre dropped from €2.1 m$^{-3}$ in 1970 to €0.46 m$^{-3}$ in 2003. In 2004, the Centre for Hydrographic Studies (CEDEX) carried out an analysis of desalination, establishing forecasts based on large facilities (producing over 60,000 m$^3$ day$^{-1}$) running at full capacity and with stable energy prices. The results of this research formed the basis for the launching of the AGUA Programme seeing as, according to the studies, unit production costs could reach values of below €0.40 m$^{-3}$. However, the unit cost of desalination envisaged in the AGUA Programme amounted to €0.91 m$^{-3}$, taking 2008 as the reference.

Estevan (2008) found that unit operating costs, excluding investment, for a reverse osmosis plant with a capacity of around 30,000 m$^3$ day$^{-1}$ and running at full annual capacity were between €0.35 and €0.45 m$^{-3}$. According to Olcina and Moltó (2010), the total cost of desalinated water in 2008 ranged from €0.38 to €0.60 m$^{-3}$. In a comprehensive analysis of international and Spanish desalination projects, Martínez Vicente (2009) observed that the cost of seawater reverse osmosis desalination ranged from €0.54 m$^{-3}$ at 140,000 m$^3$ day$^{-1}$ macro-plant capacity using a well intake system, to €0.69 m$^{-3}$ at small plants with open intake systems. Therefore, focusing operations on large plants is a desirable trend in the medium term in order to reduce the costs involved in obtaining desalinated water.

In the aforementioned seminar, 'Water and Sustainable Development', Professor Daniel Prats also pointed out that there had been a significant decrease in the total production cost of desalinated water, falling from €2 m$^{-3}$ in 1970 to only €0.5 m$^{-3}$ in 2014. Evidently, these data are based on the premise that the plant is operating at its nominal production capacity. Therefore, these costs would increase and they would not be competitive at all compared with other cheaper, conventional sources. In the case of the *Mancomunidad de los Canales del Taibilla*, the average total cost of water produced at its plants in 2016 totalled €0.62 m$^{-3}$, with values ranging between €0.54 m$^{-3}$ at the San Pedro del Pinatar II plant, €0.75 m$^{-3}$ at the Canal de Alicante I plant, €0.71 m$^{-3}$ at the Mutxamel plant, and €0.55 m$^{-3}$ at the Torrevieja plant. These differences were due to the specific energy consumption of these plants, which ranged from 3.2 to 4.8 kWh m$^{-3}$.

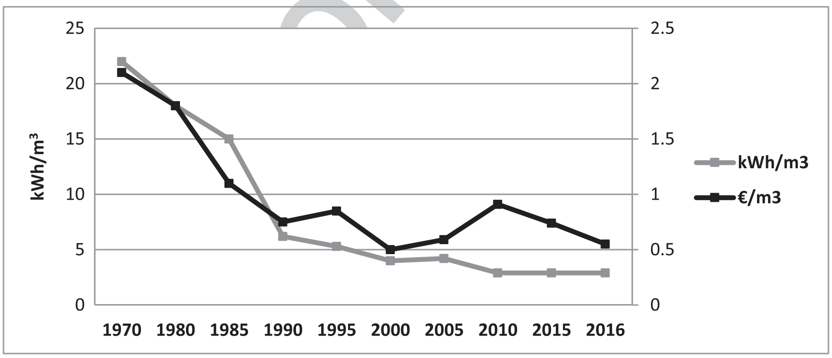


Figure 2 Evolution of the energy consumption (kWh m$^{-3}$) and price of desalination (€ m$^{-3}$) in Spain, 1970–2016
Source: Prats and Melgarejo (2006); Olcina and Moltó (2010); Del Villar (2014); Interviews. Elaborated by the authors

Nowadays, depending on the size, design, type of intake, and production volume in the large desalination plants that use reverse osmosis systems that were built as part of the AGUA Programme on the coast of the regions of Valencia and Murcia, in terms of the water supply coming straight from the desalination plant, the costs range from €0.70 to €0.90 $m^{-3}$ including depreciation. In the small brackish water desalination plants operating on the Valencian coast, depending on the technical features of the treatment and the conductivity of the groundwater, the costs range from €0.25 to €0.45 $m^{-3}$ (Abad & Moreno, 2015). These are higher than those incurred by other sources of conventional high-level water supply in the regions of Murcia and Valencia, and without accounting for other distribution, maintenance, and investment payback costs. For example, the Tagus-Segura transfer has an energy consumption rate of 1.11 kWh $m^{-3}$, and supplies water for urban and agricultural use at a rate of €0.09 $m^{-3}$. The average high-level water supply tariff paid by the irrigators in the Segura basin is €0.14 $m^{-3}$, while the low-level water supply rate amounts to €0.17 $m^{-3}$. Depending on the source of the water supply, irrigation water prices range from €0.03 $m^{-3}$, with surface water, to €0.20 $m^{-3}$ with groundwater (Calatrava & Martínez, 2016). The costs incurred in desalination are also higher than those paid by the suppliers of drinking water. The *Consorcio de Aguas de la Marina Baja* (province of Alicante, Region of Valencia) guarantees the water supply to tourist municipalities such as Benidorm at €0.36 $m^{-3}$. This final cost includes different sources of supply provided by groundwater resources at €0.07 $m^{-3}$; treated water from reservoirs at €0.08 $m^{-3}$; and purified water using ultrafiltration and desalination at €0.28 $m^{-3}$ (Gil & Rico, 2015).

*Desalination in Spain: a politicised water resource*

Besides technological, social, environmental, and economic costs, desalination has also suffered from the extreme politicisation of the water debate (Rancière, 2006). With the cancellation of the Ebro transfer (2004), the two legislatures presided over by governments led by the *Partido Socialista* (2004–08, 2008–11) came up against strong opposition to water policies in the regions of Valencia and Murcia. Because of delays in the AGUA Programme and the high cost of supplying desalinated water, the regional governments of Murcia and Valencia, led by the *Partido Popular*, launched fierce campaigns against desalination in favour of the need to reinstate the original National Hydrological Plan (2001) and the cancelled Ebro transfer. However, after the 2011 general election, when the *Partido Popular* regained power, this issue was forgotten and the Ebro transfer has disappeared from the national political agenda, and they accepted desalination and finished the construction of the desalination plants. Some authors also argue that 'after the electoral defeat of the Socialist Party in the elections of 2011, the AGUA Programme quietly disappeared from the political discourse of the successor conservative government headed by Mariano Rajoy (Partido Popular)' (Swyngedouw, 2015, p.219).

Although the national political debate was reduced or ended, since 2014 this debate has emerged strongly on the regional scale (Region of Castilla-La Mancha between Valencia and Murcia) because of the start of the current drought, with the Tagus-Segura cuts and the start of the working of some desalination plants. This regional political debate is also taking place within the same political party. For example, the Government of the Region of Valencia (*Partido Socialista*) defends the Tagus-Segura scheme but the Government of the Region of Castilla-La Mancha (also *Partido Socialista*) could 'close' this infrastructure and they are in agreement with the subsidisation of desalination in the Spanish Mediterranean to replace the Tagus-Segura transfer (Europa Press, 2015).

Some desalination plants were built to supply water for new urban and tourist uses that were never built, for example, the desalination plants of Sagunto, Oropesa, Moncófar, and Mutxamel (Region of Valencia). The Oropesa and Moncófar plants are in the testing phase, while the Sagunto plant has been completed although it is not yet operational. In the province of Alicante, the Torrevieja plant ($80 \times 10^6$ $m^3$ $year^{-1}$) is operating at 40 per cent of its capacity ($30 \times 10^6$ $m^3$ $year^{-1}$) and it delivers water to the Pedrera reservoir and then subsequently supplies irrigation water to areas along the Tagus-Segura transfer. Work on the Mutxamel plant has been completed. It was built with the aim of supplying water to the 'mega-urban plan' of Rabasa (15,000 houses in the city of Alicante). However, this plant has been in operation since June 2015 (operating at 40% of its capacity—$5 \times 10^6$ $m^3$ $year^{-1}$) to supply water to the tourist city of Benidorm (500,000 inhabitants approximately in summer and more than 130,000 hotel rooms) because of the scarcity of water in the *Consorcio de Aguas de la Marina Baja.*

In an interview on 9 April 2012, Miguel Arias Cañete (the Minister of Agriculture, Food and the Environment in Spain) called the AGUA Programme a 'resounding failure', 'catastrophic', and 'chaotic'. Out of the 51 new facilities envisaged in Spain in 2009, only 17 desalination plants are in operation, after an investment of €1,664 million, and these are operating at 16.45 per cent of their capacity (Enguix & Cerrillo, 2012). In addition, the Regional Government of Valencia has argued that water desalination has already led to a 35 per cent increase in domestic consumption prices in the Alicante municipalities that are supplied by the *Mancomunidad de los Canales del Taibilla*. Farmers cannot afford such high prices, either. The price of desalinated water for irrigation is so high that, according to the Minister of Agriculture, Food and the Environment, it would be necessary to resort to '*a series of hidden subsidies*'. The Minister also estimated the cost of desalinated water at €1.1 $m^{-3}$, an amount far higher than that which the sector can bear, which is €0.30 $m^{-3}$ at the most.

There have been recent initiatives to boost production of desalinated water, such as the Government's proposal to subsidise this resource. Currently, in the southeast of Spain, farmers are paying €0.30 $m^{-3}$. The State has covered the rest of the cost since 2015 and this subsidisation will be extended to 2017. That being the case, the water shortage problems, aggravated during periods of drought, intensify people's perception that water resource planning is not producing appropriate solutions for the demands of the irrigators. Leading newspaper *Diario La Verdad*, highly influential in the regions of Murcia and Valencia, covered the news with the headline *Historic Agreement to lower the price of desalinated water during the drought*, in an article printed on 15 October 2015. It was reported that the closure of the deal in the negotiations with the Ministry of Agriculture and the Environment allowed irrigators to gain access to $50 \times 10^6$ $m^3$ $year^{-1}$ of desalinated water from the desalination plants of Águilas, Torrevieja, and Valdelentisco at a price of €0.30 $m^{-3}$.

Finally, the production of desalinated water in Spain has caused controversy, and even aroused suspicions of corruption in relation to the granting of construction project contracts. In January 2016, the top executives of the public company Acuamed were arrested in relation to the case *Operación Frontino*. Among them was the company's Chief Executive Officer, together with prominent executives from Spanish engineering and construction firms, beneficiaries of investment from the AGUA Programme. They were accused of the alleged perpetration of crimes concerning the embezzlement of public funds, the exercise of undue influence, bribery, conspiracy to alter the price of the contracts, the breach of official duties, and forgery.

## Discussion

Desalination is presented as being a radical departure from traditional water management solutions, which relied on large terrestrial infrastructures to transport water substantial distances, while in essence it was merely reproducing an expansionist hydro-modernist vision for development (March *et al*., 2014). Desalination established extraordinary new techno-social configurations, while preserving the same underlying logics of developmental, growth-oriented water governance. This resource was presented as a technologically advanced, 'environmentally friendly', and uncontested local water source, and as such, it was touted as being a win-win 'scalar fix' to Spain's water challenges (Swyngedouw & Williams, 2016). Apart from the high-quality water produced, the main advantage is undoubtedly that desalination represents a virtually inexhaustible source and, in countries such as Spain, especially on islands and in Mediterranean regions, it offers a supply free of the constant regional and political tension between transferor and recipient basins (Martínez-Fernández, 2009). This advantage, which is structurally valid in semi-arid, subtropical environments, and in situations such as the recent droughts that have occurred, for example, in California (USA), is so evident that it should be enough to prompt a quest to identify the mechanisms necessary to offset the aforesaid disadvantages.

The results shown in this study can be summarised in the assessments provided by other authors (Swyngedouw & Williams, 2016). In one example of a badly adapted technique, one of the advantages of desalination is that this resource helps reduce environmental problems caused by the overexploitation of aquifers, with sequelae such as saltwater intrusion and the diffuse pollution from agricultural activity. It can also become a resource that is not affected by weather conditions or variations in the availability of continental water resources (Feitelson & Rosenthal, 2012), and what is more, it could end political, social, and inter-territorial conflict caused by water transfers between recipient and transferor regions (Downward & Taylor, 2007; Kohlhoff & Roberts, 2007; Saurí, 2003).

The price of desalinated water has meant that some users find it difficult to access this resource and some are even excluded from such access, among them, farmers using water for agricultural crops and social groups with low purchasing power, which parallels the experience of marginal people in areas of Southern California and Mexico (McEvoy, 2014). With regard to farmers, except for those growing flowers in greenhouses, those who use the water supply for irrigation (winter vegetables and citrus fruit) cannot afford to pay for desalinated water and maintain the viability of their farms. As for the social groups, the gradual and constant increase of the low-level water supply rate in the last few years has resulted in an increase of defaulting and fraud (March *et al*., 2015).

Desalination is closely connected to broader processes of depoliticisation (Swyngedouw & Williams, 2016). In this sense, despite the fact that desalination in Spain has been politicised, presently, there is no national political debate associated with desalination, because those who used to oppose this new resource, and who are now in power (*Partido Popular*), have opened the desalination plants built with the Socialist Government. However, an old 'water war' has recommenced on the regional scale between farmers and political parties of the regions of Castilla-La Mancha, Murcia, and Valencia.

Energy costs are also very high, especially in countries such as Spain, which largely depends on external sources, and this must be reduced through technological advances made in traditional desalination methods and by introducing new techniques, or by using renewable sources of energy so that desalination becomes a more attractive option. In addition to energy costs, there are also environmental costs derived from $CO_2$ emissions and brine discharge. In both cases, the aforesaid technological improvements and better waste management are necessary to reduce this impact.

Furthermore, desalination was promoted to resolve these problems of water scarcity and droughts in Spain, but it has been largely forgotten that many of these desalination plants were built to guarantee new urban and tourist uses—an urban model that is characterised by the presence of new urban natures like gardens and pools that increase water demand (Morote *et al*., 2016b).

In the case of the southeast of Spain, desalination could never totally replace, for example, the Tagus-Segura scheme ($600 \times 10^6$ $m^3$ $year^{-1}$). But with the new rules for operation of this infrastructure (since 2014) and the reduction of water resources because of the current drought, desalination is a temporary solution to guarantee water supply for urban uses but not to totally guarantee agricultural uses (if they are not subsidised). The detractors of the Tagus-Segura transfer (from Castilla-La Mancha) argue that in the southeast of Spain, desalination must replace this infrastructure for environmental reasons and it should be subsidised.

All of these comments and controversies are enforcing the argument of water dependence and the perception that there is no water. However, in Castilla-La Mancha, some new urban plans and residential developments are planned in Ciudad Real, Chinchilla (Albacete) (residential development of 'La Losilla' with 1,800 houses and a golf course) and Seseña (Toledo) (13,000 houses), which will be supplied with water from the Tagus-Segura. Moreover, in the last decade, in Castilla-La Mancha, the irrigation surface was increased from 447,333 to 512,223 ha. In addition, it is important to explain that, thanks to the Tagus-Segura transfer, in 59 towns of Castilla-La Mancha, the water supply is guaranteed, as is the improvement of the environmental level of the Natural Park of *Tablas de Daimiel*.

With regard to water dependence, for example, the government of Spain announced in September 2016 that desalination will be subsidised for another year in the Torrevieja plant (Region of Valencia) and Valdelentisco (Region of Murcia) with a price of €0.30 $m^{-3}$. With these measures, irrigators are very successful and there is currently an increase in the demand for desalinated water for rural uses. According to recent meetings with the irrigators from the south of Alicante, they are in agreement with the signing of a contract for 10 years to use subsidised desalinated water at this price. With this action, the production of desalinated water in the Torrevieja plant will be $80 \times 10^6$ $m^3$ $year^{-1}$ (top level capacity). Moreover, energy companies have economic interests in the boosting of desalination. This is the case of the Torrevieja plant where Acciona (the same company that manages the plant and supplies the energy) has reduced the energy cost (€0.07 $kWh^{-1}$) and will facilitate the increase in production.

At the moment, it does not seem as though the demand for drinking water is going to recover in the short term, because of the technical improvements made in the high and low-level water supply service, and considering the consolidation of domestic water saving habits, with the incorporation of water-efficient taps and household electrical appliances so that modules of less than 119 L per inhabitant per day can be attained (Gil *et al*., 2015;

Morote *et al*., 2016a). Furthermore, despite the slight economic improvement in the last 2 years thanks to the positive trends in tourism and the real estate acquired by foreigners in coastal towns, it still does not seem as if the property market is going to recover the levels of sales it had before the crisis of 2007/08. As a result of this, there is an excess supply of desalinated water, with oversized desalination plants that have much higher production capacities than needed, even to cope with periods of intense drought.

## Conclusions

The water debate in Spain will not result in ‘ground-breaking ideas’ because it will be centred on ‘evolutional ideas’, in other words, with a gradual evolution of the hydraulic paradigm to a new model of water management and the enhancement of all conventional and non-conventional water resources and thinking about current and future realities. In mainland Spain, desalinated water has not meant ‘more water’ for urban, tourist, or agricultural developments but ‘less water and more expensive’ than water from existing or planned conventional hydraulic works such as dams and transfers—this because it internalises costs to a greater extent than conventional water resources. The specific singularity of desalination in Spain is that, traditionally, the political conservative and pro-growth socio-economic elites have opposed water desalination development because they demand the continuation of a free, or inexpensive, water supply for economic development, without internalisation of financial, social, and ecological costs.

The main findings of this study are that desalination and water transfer schemes are not panaceas in themselves; rather, they should be considered in terms of technological parameters tailored to the circumstances of each geographical and socio-economic environment. Desalination presents a number of drawbacks that must be taken into account. Its high price is still a major problem, because these costs are only feasible for urban or recreational uses with high added value or those that are socially necessary. The worst affected sector in this scenario is agriculture, especially farms that are based on traditional irrigation systems or those using cutting-edge methods. Only a subsidised price or parity with the price of other, cheaper methods—existing or viable water transfer schemes and the use of reclaimed waste water or rainwater—in a sustainable mix, could convince farmers of the benefits.

Perhaps the most important lesson to be learnt from the Spanish case is that desalination is neither good nor bad; its suitability depends largely on the context. Thus, it should not be used as an opportunity for untrammelled increases in water supply, or as an excuse to completely overlook other resources or tailor supply to demand, for example, by adapting water quality to the purpose for which it will be used (Loftus & March, 2016; Swyngedouw, 2013; Swyngedouw & Williams, 2016).

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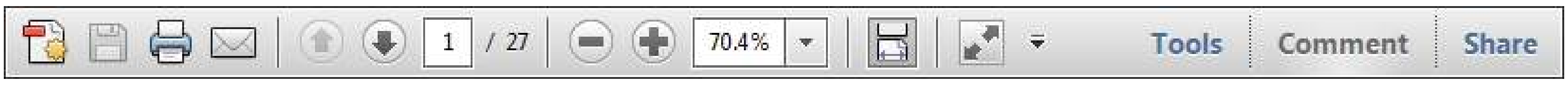
| Q42 | AUTHOR: Please supply the issue number for reference “Morote 2016. | |
| Q43 | AUTHOR: Please supply the issue number for reference "Morote and Hernández 2016a". | |
| Q44 | AUTHOR: Please supply the issue number for reference "Latta and Gómez 2014". | |
| Q45 | AUTHOR: Please supply the issue number for reference "Saurí 2003". | |
| Q46 | AUTHOR: Please supply the issue number for reference "Saurí and Del Moral 2001". | |
| Q47 | AUTHOR: Please supply the issue number for reference "Siddiqui and Díaz 2011". | |
| Q48 | AUTHOR: Please supply the issue number for reference "Olcina and Moltó 2010". | |
| Q49 | AUTHOR: Please supply the issue number for reference "Rico 2010". | |
| Q50 | AUTHOR: Please supply the issue number for reference "Sadhwani et al. 2005". | |

WILEY

# USING e-ANNOTATION TOOLS FOR ELECTRONIC PROOF CORRECTION

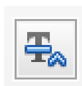
**Required software to e-Annotate PDFs: Adobe Acrobat Professional or Adobe Reader (version 7.0 or above). (Note that this document uses screenshots from Adobe Reader X)**
**The latest version of Acrobat Reader can be downloaded for free at: http://get.adobe.com/uk/reader/**

Once you have Acrobat Reader open on your computer, click on the Comment tab at the right of the toolbar:




This will open up a panel down the right side of the document. The majority of tools you will use for annotating your proof will be in the Annotations section, pictured opposite. We've picked out some of these tools below:

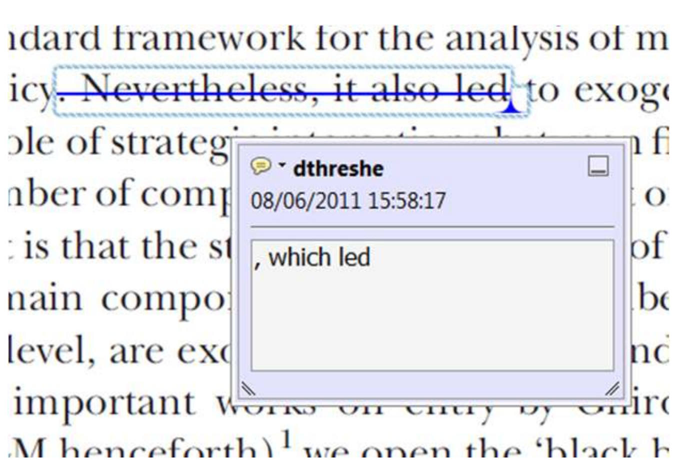

## 1. Replace (Ins) Tool – for replacing text.



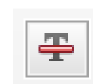
Strikes a line through text and opens up a text box where replacement text can be entered.

**How to use it**

- Highlight a word or sentence.
- Click on the Replace (Ins) icon in the Annotations section.
- Type the replacement text into the blue box that appears.



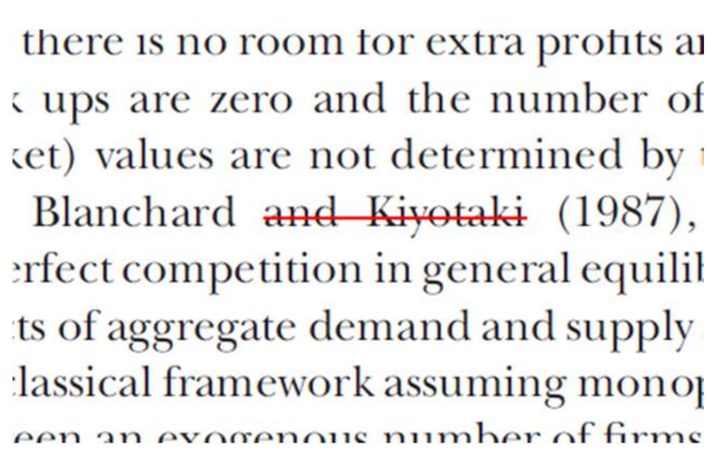

## 2. Strikethrough (Del) Tool – for deleting text.



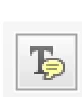
Strikes a red line through text that is to be deleted.

**How to use it**

- Highlight a word or sentence.
- Click on the Strikethrough (Del) icon in the Annotations section.



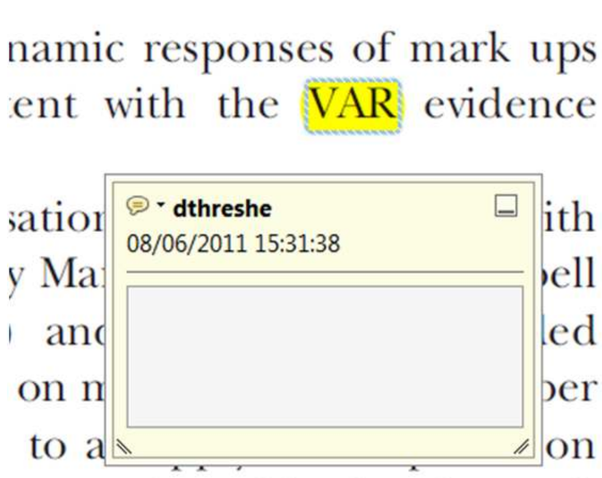
## 3. Add note to text Tool – for highlighting a section to be changed to bold or italic.



Highlights text in yellow and opens up a text box where comments can be entered.

**How to use it**

- Highlight the relevant section of text.
- Click on the Add note to text icon in the Annotations section.
- Type instruction on what should be changed regarding the text into the yellow box that appears.

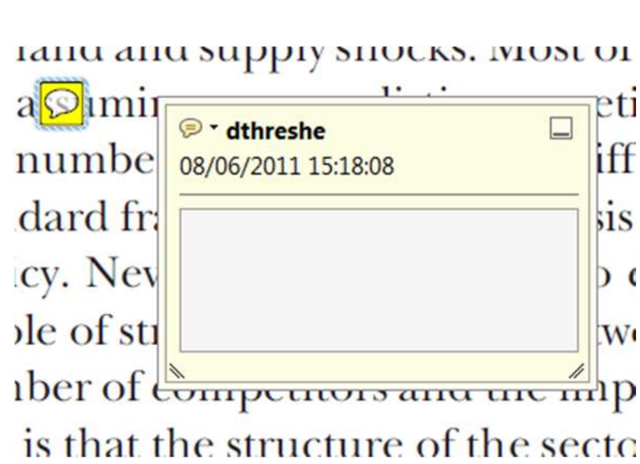



## 4. Add sticky note Tool – for making notes at specific points in the text.

Marks a point in the proof where a comment needs to be highlighted.

**How to use it**

- Click on the Add sticky note icon in the Annotations section.
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the yellow box that appears.

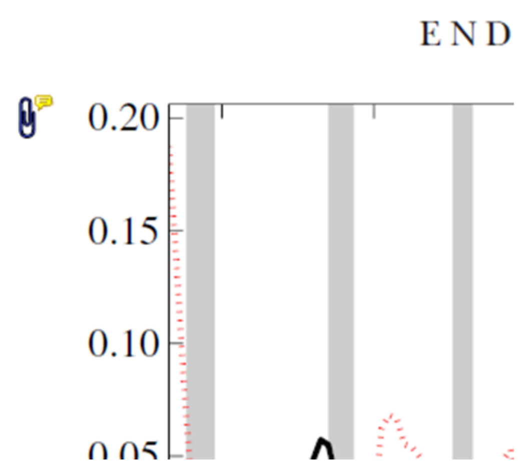


**5. Attach File Tool – for inserting large amounts of text or replacement figures.**

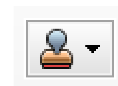
Inserts an icon linking to the attached file in the appropriate pace in the text.

**How to use it**

- Click on the Attach File icon in the Annotations section.
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.



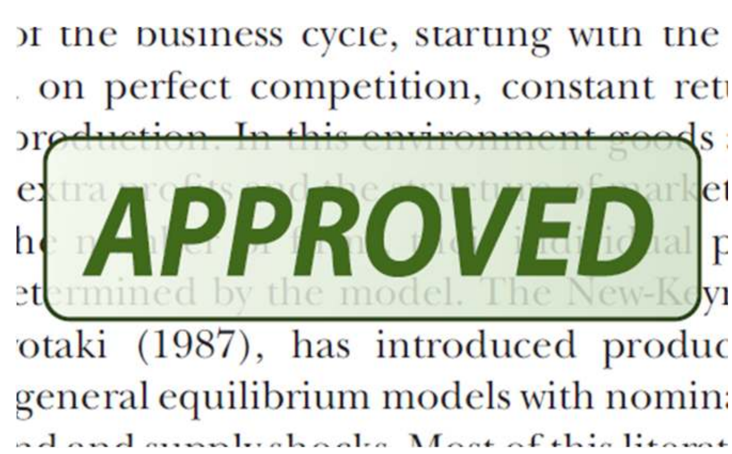

**6. Add stamp Tool – for approving a proof if no corrections are required.**

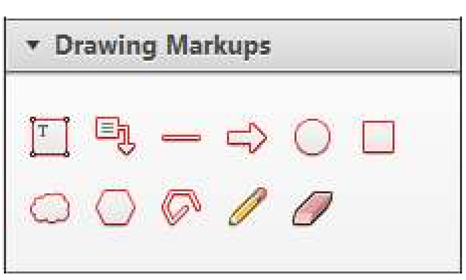


Inserts a selected stamp onto an appropriate place in the proof.

**How to use it**

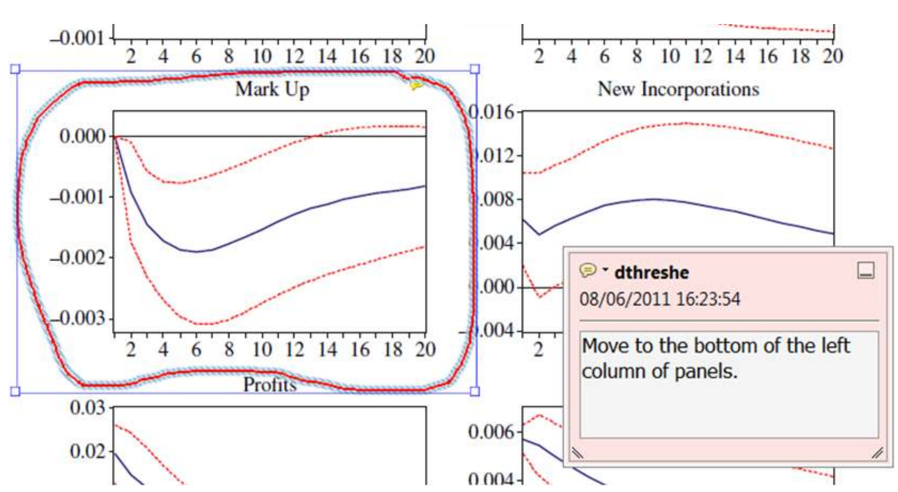
- Click on the Add stamp icon in the Annotations section.
- Select the stamp you want to use. (The Approved stamp is usually available directly in the menu that appears).
- Click on the proof where you'd like the stamp to appear. (Where a proof is to be approved as it is, this would normally be on the first page).




**7. Drawing Markups Tools – for drawing shapes, lines and freeform annotations on proofs and commenting on these marks.**

Allows shapes, lines and freeform annotations to be drawn on proofs and for comment to be made on these marks..




**How to use it**

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, move the cursor over the shape until an arrowhead appears.
- Double click on the shape and type any text in the red box that appears.

**For further information on how to annotate proofs, click on the Help menu to reveal a list of further options:**