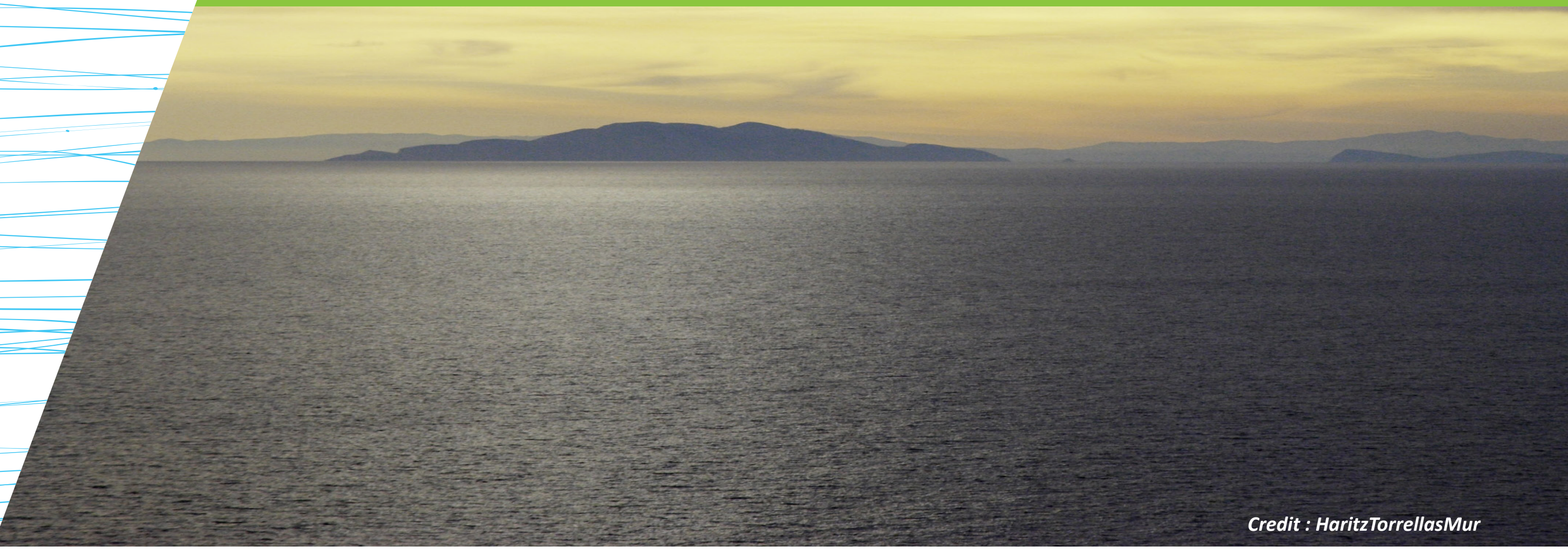
Opportunities and risks of desalination activities in the Mediterranean in the face of climate change and growing water needs



PLAN BLEU NOTES
#45
FEBRUARY 2024
Plan Bleu

The Mediterranean Basin is a hotspot for climate change. The effects of this on the availability of water resources, which are already highly unequal depending on national socio-economic and environmental contexts, are becoming increasingly significant. This is compounded by significant population growth, causing increasing demand for water in the domestic, industrial, tourism and agricultural sectors. This dual challenge makes it crucial to redefine the use of water resources as a common good. Desalination, although considered a controversial industrial sector because of the associated risks (impacts, economic and energy costs), is seeing increasing opportunities for development. We worked with a statistical and mapping analysis of the DesalData database[1], to present major trends and developments in the Mediterranean desalination sector since 2013.

Time and spatial diversity of plant production systems

There is considerable diversity in the spatial distribution of the number of plants and the use of different production system technologies over the different periods (1979-2013 and 2014-2023), with uneven distribution across countries (fig1).

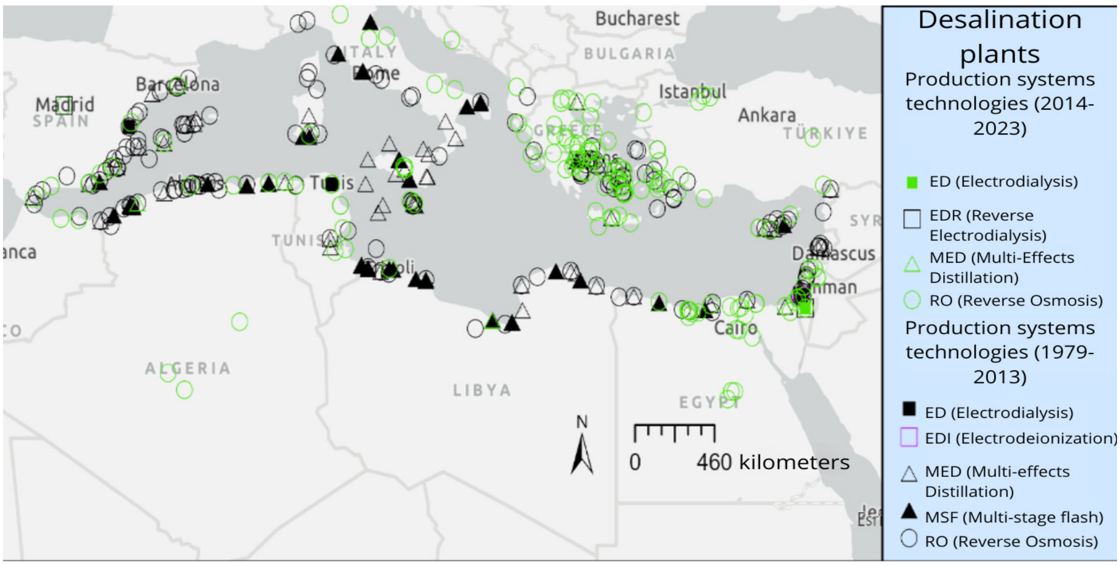


Figure 1-Spatial distribution of desalination plants and production system technologies from 1979 to 2023.

1 The data taken, analysed and presented in this document cover operational desalination plants drawing their "feeding waters" from seawater in coastal areas. Furthermore, the plant production system technologies discussed in this report are mainly membrane distillation (reverse osmosis) and thermal processes: Multi-Stage-Flash (MSF) and Multi Effect Distillation (MED).

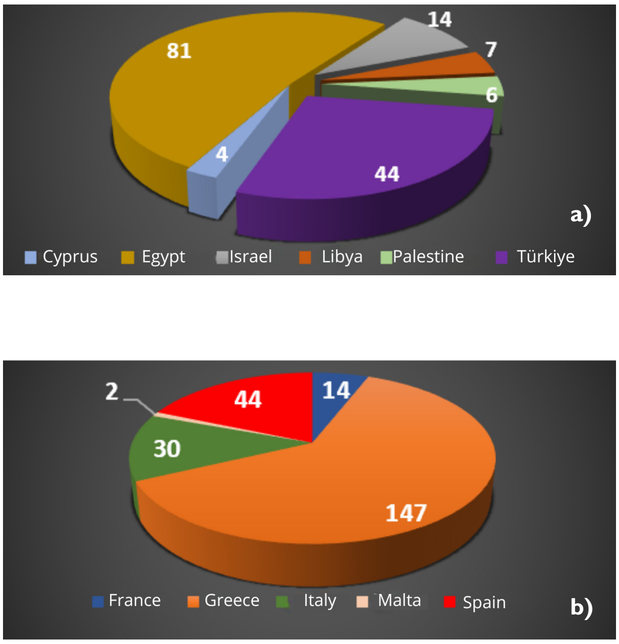


Figure 2-Distribution of plants in south-eastern Mediterranean countries (a), north-western Mediterranean countries (b).

With 147 desalination plants, Greece far exceeds all other Mediterranean countries in terms of the number of plants located on its territory, although this gap is narrowing as other countries have stepped up their efforts over the last ten years. This is around 3 times more than Spain, which has the second-highest number of desalination plants in western countries. As a result, technology trends can be observed between the northern and southern Mediterranean over four time periods (fig3).

Generally speaking, Reverse Osmosis (RO) technologies are favoured over thermal technologies, despite some differences: between 2000 and 2016, there were 121 RO plants in northern Mediterranean countries, compared to 108 in southern Mediterranean countries. On both sides of the Mediterranean, the number of new thermal technology plants (MSF-MED) slowed down between 1979 and 2023. However, this type of technology seems to have been less quickly abandoned by southern countries than northern countries. Between 2000 and 2016, southern countries built more thermal technology plants (27) than northern countries (16).

Contrasting plant production capacities

Desalination plant production capacities vary widely from one country to another depending on socio-economic and environmental contexts, and the plants' different production systems. Average plant production capacities (m³/day) significantly increased between 2013 and 2023, particularly in the Levantine (fig4a). Desalinated water production capacity in the Mediterranean has increased by around 446.8% (from 940,842 m³/day to 5,144,441 m³/day) in 10 years (compared with 110 million m3/day on a global scale in 2023). On a regional Mediterranean scale, unit production capacities in the Aegean Sea decreased between 2013 and 2023, with many plants in 2023 having production capacities in the 0-1000 m³/day range.

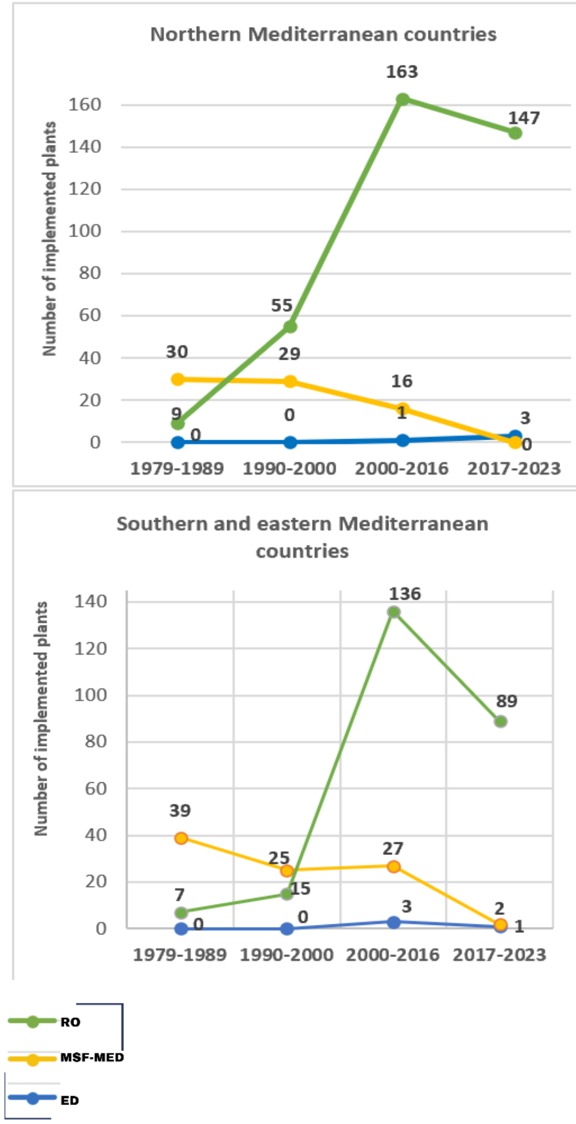
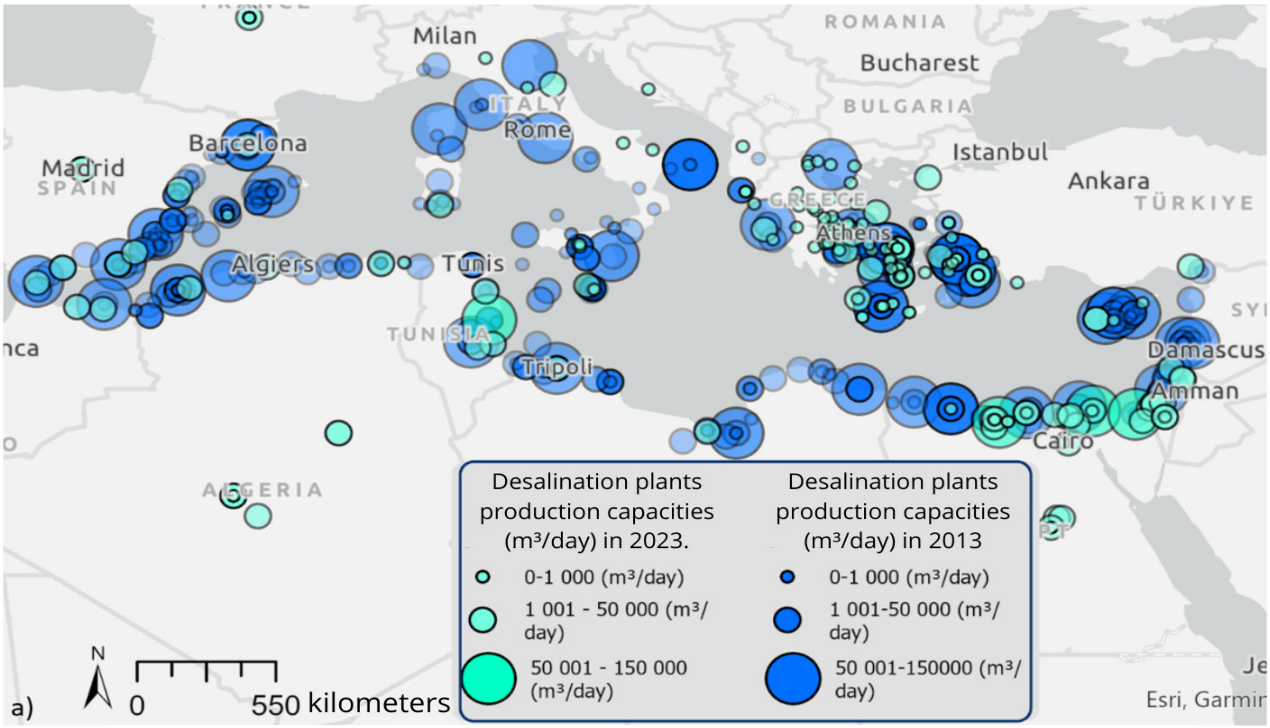


Figure 3-Change in the number of desalination plants according to type of technology for four time periods, from 1979 to 2023.

Conversely, in some areas (e.g. the Gulf of Gabès in Tunisia and the Levantine Basin), unit production has increased since 2013, although the analysis does not show whether this is due to the opening of new units or the renovation of old ones. These capacities increased by around 367% for the Levantine Basin alone (from 580,120 m³/day to 2,709,122 m³/day). On the other hand, the histogram of average desalination plant capacity by country clearly shows the dissonance between the number of plants in each country and the daily national production of each country. The southern Mediterranean has fewer plants than the northern Mediterranean, but far greater production capacities. The 5 countries that stand out in terms of national production capacity are all in the South: Israel, Morocco, Algeria, Tunisia and Egypt. Israel has an average production capacity of 84,850 m³/day, around 2.3 times more than Morocco in 2nd place (36,779 m³/day). Greece has the largest number of plants in the Mediterranean, but produces on average 17 times less than Egypt for around 1.8 times more plants on its territory (fig4b). Most countries in the southern Mediterranean have much higher national desalinated water production capacities (between 3,014 m³/day and 84,850 m³/day) than those in the North (between 120 m³/day and 4,700 m³/day).



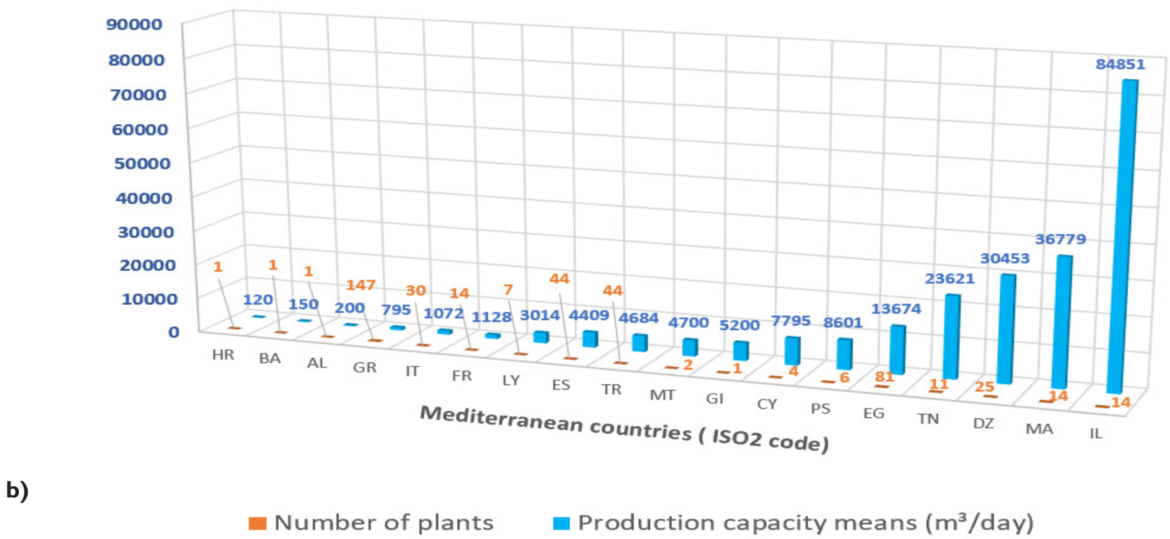


Figure 4-Variation in plant production capacity, with a map showing the comparative daily yields for each plant between for each plant between 2013 and 2023 (a) and a histogram of average daily desalinated water production per country and the number of associated plants in 2023 (b).

Contrasting uses of desalinated water

The uses of desalinated water vary according to local needs, type of customer and country (fig5). For most southern countries, by 2023, the priority customers were municipalities, presumably to compensate for drought events (MSSD indicator 12), defined as a volume of water <1000 m³/year/person, which are becoming increasingly frequent and intense in these arid Mediterranean regions. Customer types have therefore evolved over time, with municipalities, for example, accounting for the majority of customers in 2013 (266 plants or 49% of the total).

Since 2013, drastic changes in the customer base of plants on a national scale have been observed. Municipalities ranked 2nd in the 2013 customer base, but are now the main customers for plants in southern Mediterranean countries, supplying drinking water to their populations. However, this trend could change, as since 2014 there has been a sharp increase in the number of desalination plants whose main customer is irrigation (+90%).

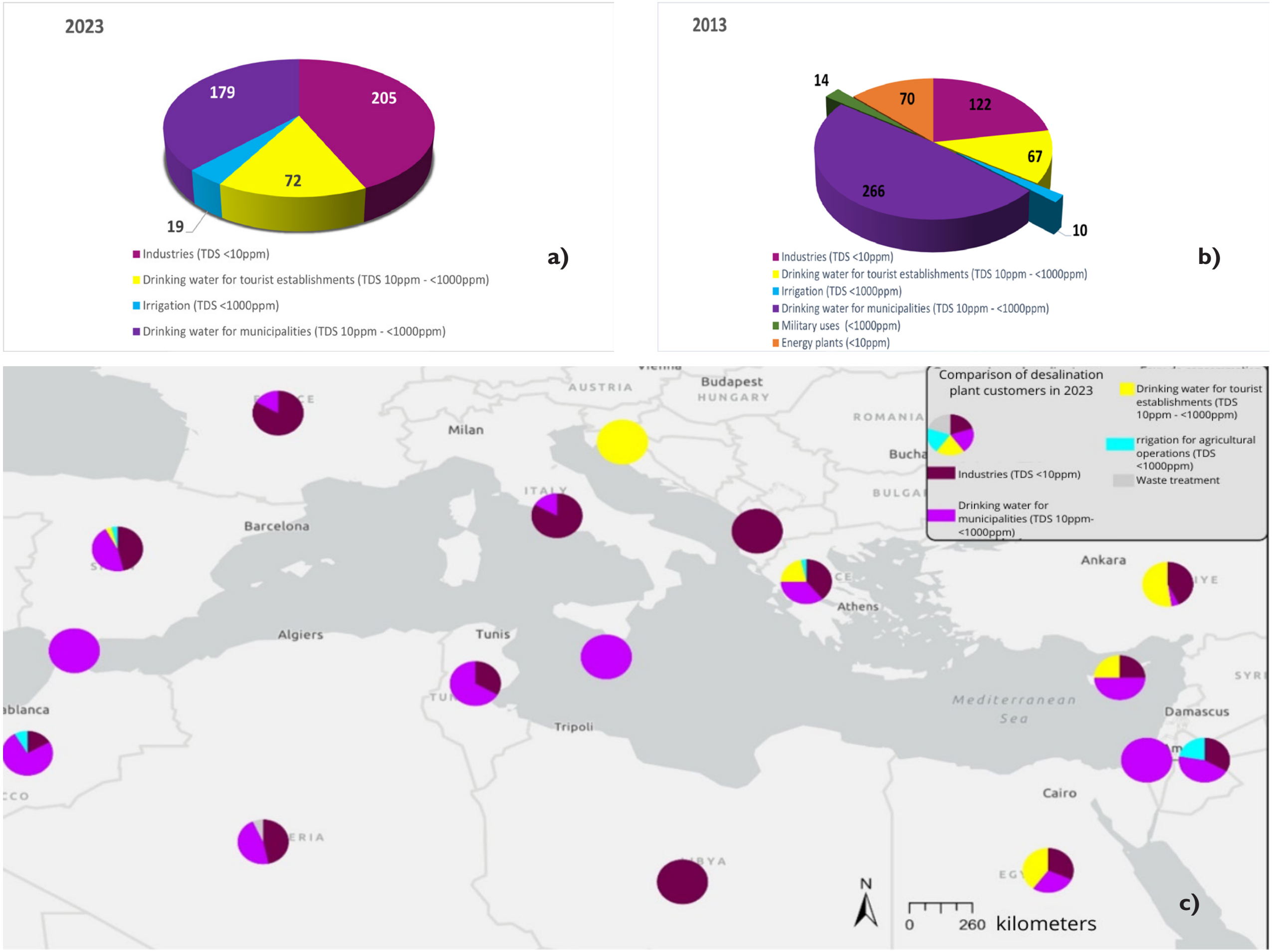


Figure 5-Comparison of customer bases for the plants (number of clients by sector) for the year 2023 (a) and 2013 (b). Cartographic representation of the distribution of these customers on a national scale in 2023 (c).

Already, the number of plants whose main customers are municipalities has fallen from 266 customers in 2013 to 179 customers in 2023, now accounting for just 37% of desalination plants (fig5). Conversely, since 2014, water requirements have been growing for irrigation and tourism facilities (+7.5%). In 2023, water requirements for industry had increased, accounting for 43% of customers (205 plants). This represents an increase of almost 40% in plants dedicated to industry since 2013. Two customers have also disappeared (military uses and power stations). Since this year, plant customers have been more restricted in view of the growing demand for water. These observable differences in plant customer bases can be partly explained by increasingly frequent and intense water stress.

Risks associated with desalination activities

Although desalination plants have the potential to alleviate water shortages of varying degrees (SoED, 2020), this industrial sector is not without risks.

Economic risks

An upward increase in capital expenditure (CAPEX) and operating costs (OPEX), in millions of euros, is expected by 2027 and can already be observed (fig-6). Furthermore, projected variations in investment costs are higher than those for operating costs. Only Turkey (-16.80%) and Cyprus (-18.80%) show decreasing investment costs by 2027. Spain is the only country where operating costs will fall by 2027 (-0.05%).

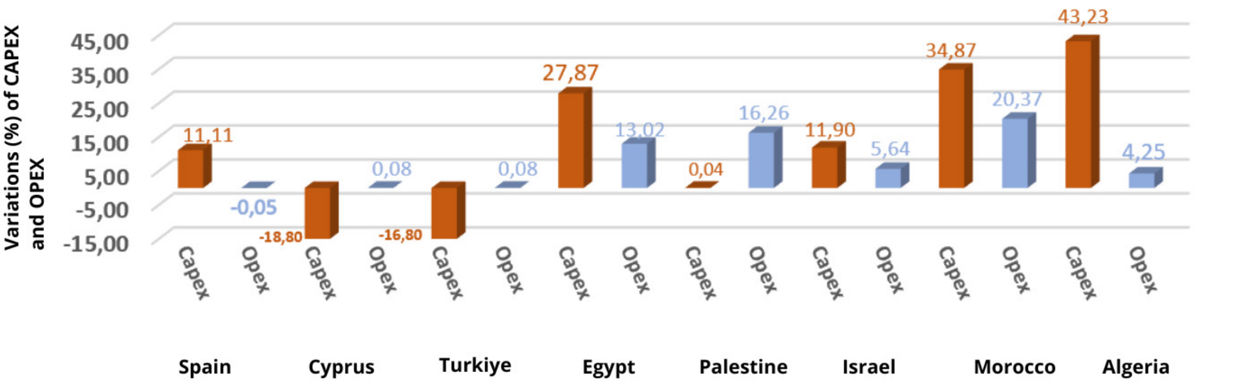


Figure 6-Average annual variations in investment costs (CAPEX) and operating costs (OPEX) from 2018 to 2027 for different Mediterranean countries.

In some countries, such as Algeria and Morocco, investment costs have risen by more than 30%, while operating costs have risen by no more than 20%. infrastructure, technologies, plants and equipment. This is a good sign, as it suggests that they are modernising and trying to be more competitive in this business sector.

Environmental risks

In addition to the expected massive economic expenditure, there are also significant environmental impacts to be taken into account, particularly through the impact of brine disposal in coastal marine environments (See fig7). Brine has higher salinity and temperatures than the coastal waters into which they are discharged. It can cause a number of ecotoxicological impacts (increased mortalities, reduced reproduction and fecundity rates, disrupted physiological processes, etc.) on exposed benthic marine flora and fauna (El said et al., 2020; Ihsanullah et al., 2021; Chang, 2015). The nature and intensity of these impacts vary according to brine disposal conditions (bathymetry, topography, currentology, etc.) and the ability of impacted species to adapt.

Brine discharge volumes

Brine discharge volumes and desalinated water volumes are expected to be highly correlated. This is an initial assumption for Figure 6. Overall, and depending on the different plant production systems, for every 1L of desalinated water, between 1.5L and 4L of brine is produced. Israel is the country that generates the most brine (124,481.5 m³/day), but exhibits a "good ratio" between these two quantitative variables (Vbrine/Vdesalinated water <=> 124,481.5/85,591.5 = 1.45). Libya, on the other hand, with an associated ratio of around 4.10, seems to be producing excess brine volumes. In reality, the statistical dependence between the two quantitative variables (i.e. desalinated water production and brine discharge volumes) is significant (Pearson test: R^2 =0.9916). Furthermore, if the volumes of brine discharged are compared by region, plants on both shores of the Mediterranean discharge a considerable quantity of brine, which varies in a non-linear way over time (fig8). In general, brine production in southern and northern countries is on the rise, with some differences. Between 2001 and 2015, brine production in southern Mediterranean countries was increasing towards northern Mediterranean levels (overlap in 2015 with 7,881,087 m³/day versus 7,814,003 m³/day for the northern Mediterranean countries).

Furthermore, a slight decrease in discharged volumes is observed between 2018 and 2021 for northern Mediterranean countries (-2.3%), while brine production in southern countries has not decreased since 2001. However, these interpretations are limited because they are based on national annual averages (in m³/day). As the average is a quantitative indicator biased by extreme values, it is not representative of variations in brine discharge volumes within a given country. A sub-national analysis of the volumes of discharged brine would provide a more detailed view of the distribution of these volumes within the various Mediterranean countries. Nevertheless, the variations (in %) of these average volumes can be analysed as a function of time (fig9). An upward trend (+0.1% to +365%) in brine volumes discharged by each country (fig9)[2].

Degraded Posidonia Seagrass (Posidonia oceanica) meadow, located in the infralittoral zone near Cap Sugiton (Marseille, France). Photo credit: Samson Bellières, 25/11/2021.

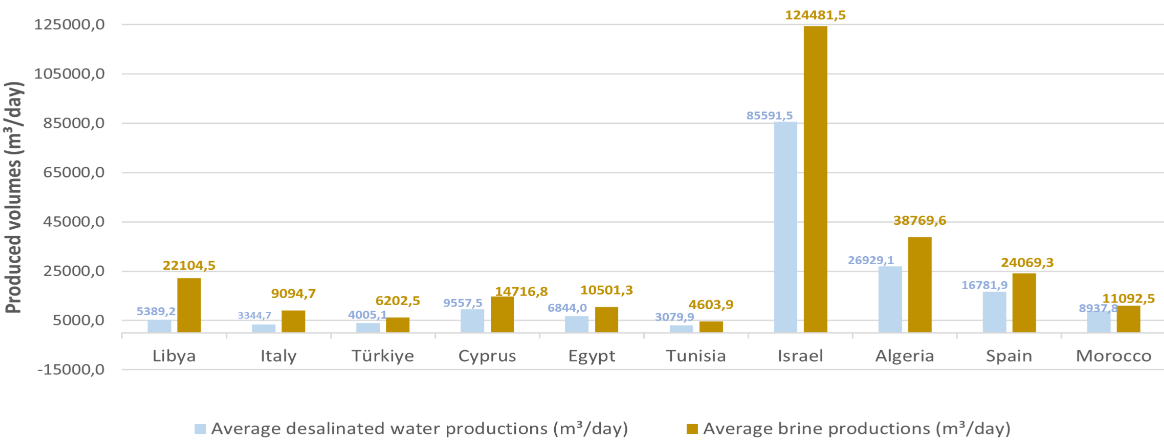


Figure 7-Annual total brine production volumes by desalination plants in northern and southern Mediterranean countries, from 2001 to 2027 (projected over the last 4 years).

2 The most extreme variation in brine volumes discharged by Israel in 2005 (+365%) has not been represented for a better graphical representation of other values. The Ashkelon plant, operational in the same year (daily production of 360,000 m³), would very likely explain this peak in production.

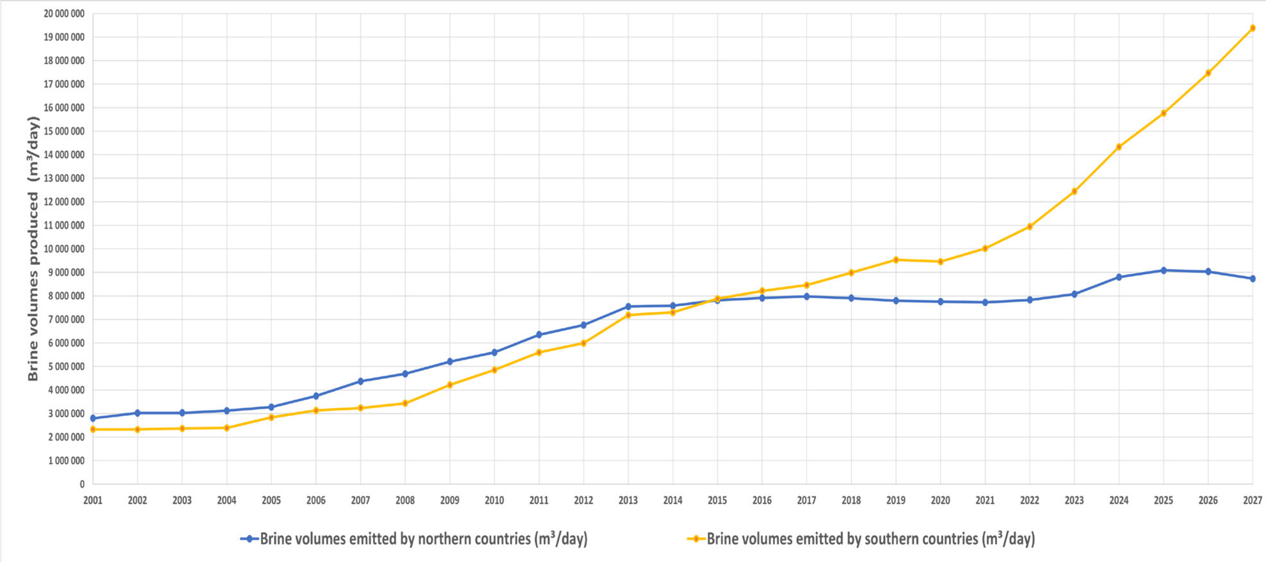


Figure 8-Annual total brine production volumes by desalination plants in northern and southern Mediterranean countries, from 2001 to 2027 (projected over the last 4 years).

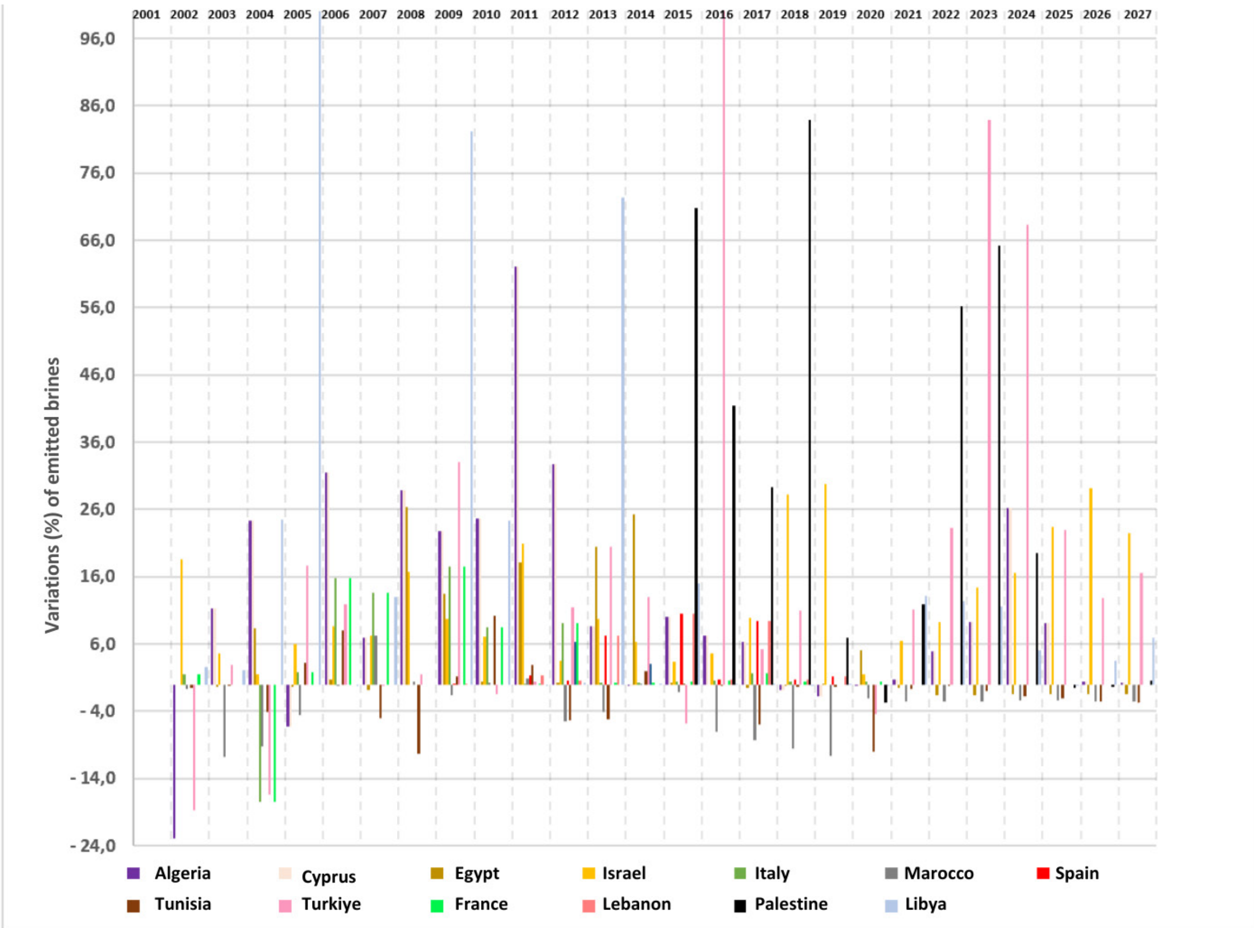


Figure 9-Interannual variations (%) in brine volumes generated on a national scale for 13 Mediterranean countries from 2001 to 2027.

Decreases in brine volumes can be observed over the period 2001-2016 (only Turkey, France, Cyprus, Italy and Tunisia), but remain minor compared to increases in brine volumes. In 2016, Turkey recorded the biggest increase in discharged brine volumes (+101.2%). Palestine shows a peak increase of 83.8% in 2018 and Israel 29.7% in 2019 in discharged brine volumes.

Since 2014, southern Mediterranean countries (Palestine, Israel and Turkey) have shown the greatest positive variations in brine volumes produced. Brine production in Cyprus, Spain, Italy, Libya and Tunisia should decline by 2027. Some countries, such as Spain and France, show little or no variation in their discharged brine volumes since 2019.

Conclusion

Since the early 1980s, desalination-related activities have been growing steadily in the Mediterranean. Desalination plants offer real potential for the production of desalinated water. In an increasingly arid Mediterranean region, where the need for water is becoming more and more acute, desalination plants can compensate for water deficits caused by extreme droughts. Investment has also increased significantly, although to different extents in each country. Most desalination plants are now concentrated on the southern shores, the Levantine Basin, the Ionian Basin and the Aegean Sea. What's more, technological innovation is helping this business sector, making it easier to build different plants over time.

However, at a regional level, there are technological disparities in the uses and volumes of desalinated water and discharged brine.

Since 2013, drastic changes in the customer base of plants on a national scale have been observed. Municipalities, which were the second ranked customer base in 2013, are now the main customers for plants in southern Mediterranean countries, in order to supply drinking water.

Desalination plants entail risks associated with their production activities. The economic and environmental risks associated with desalination activities depend directly on the specific characteristics of each plant, and indirectly on the socio-economic and environmental context of each country. Significant variations in plant investment and operating costs have already been observed, and are set to increase between now and 2027, especially for plants in southern and eastern Mediterranean countries. The amount of brine produced is also closely linked to the production of desalinated water, the associated volumes of which are systematically lower than those of brine. Furthermore, brine production varies widely, depending on the plants in each country. However, a current (2023) and projected short-term (2027) trend can be identified through this analysis. Southern Mediterranean countries discharge more brine than northern countries. Greater environmental impacts can therefore be expected.

So, despite the numerous development opportunities and a solution to growing water stress, desalination activities entail risks. From a growth and blue economy perspective, Mediterranean policymakers need to be aware of the opportunities and risks associated with this booming industrial sector, and this means improving specific governance at a regional and national level, bringing together players in the water and energy sectors (producers) and the main customers (beneficiaries). The Barcelona Convention system is intended to play a unifying role in this respect. In addition, more in-depth analyses, incorporating more socio-economic variables (foresight tools, expert feedback, participatory studies) would improve the blue economy and growth framework associated with desalination in the Mediterranean.

Desalination is a growing interest in the Mediterranean, prompting plans for plants in the Italian Tuscan archipelago, for example. The private sector is therefore investing increasingly in this branch of unconventional water resources. The rise of this business sector therefore requires revisions to the associated regulatory frameworks, particularly in terms of desalinated water production limits, which need to be adapted to the spatial and temporal variations in regional Mediterranean water demand (Navarro Barrio et al., 2021).

Finally, only seawater intake is discussed in this document. A more holistic analysis incorporating other desalination factors (other types of water intake sources, other technologies, etc.) would enable external comparisons to be made, on larger production scales.

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Editor : Antoine Laffite
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Proofreaders : François Guerquin (Plan Bleu) and Olfat Hamdam (UN)
Graphic design : Christelle El Selfani
Data source : DesalData database (Global Water Intelligence Group)
Legal deposit : N° ISSN 2606 61 06
Adress : 2 bis, Boulevard Euroméditerranée - Quai d'Arenc, 13002 Marseille