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"INVESTING FOR SUSTAINABLE DEVELOPMENT GOALS: EMERGING TRENDS IN FINANCING FOR WATER – RELATED PROJECTS"

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TABLE OF CONTENTS

FIGURES

INTRODUCTION

In 2015, as part of the "2030 Agenda for Sustainable Development", 17 Sustainable Development Goals have been set with the intention to guarantee basic human rights and decent life conditions to everyone. This vision requires immense effort by all stakeholders at international level, from politicians to regulators and investors. At present moment, we have crossed the halfway point, but global efforts have proven to be insufficient to reach the intended objectives.

This thesis focuses on Sustainable Development Goal 6 which aims to "ensure availability and sustainable management of water and sanitation for all". Water scarcity in the world is a problem that needs to be addressed today and global response is required. Water demand is surely going to increase dramatically, especially in developing countries, mainly driven by population growth and economic development.

A major obstacle in achieving SDG 6 goals is represented by the difficult of financing water-related projects, due to peculiar characteristics of water and the necessity to invest in risky and undeveloped areas of the world. The focus is to understand the magnitude of the problem, the possible solutions and the ways in which unconventional financing mechanisms can be exploited to unlock the required investments in this critical sector.

The first part glances at the current state of the art of water resources in the world, in particular distribution of freshwater resources and purposes for which they are used. Then, future expectations on water demand evolution and climate change impact are examined. The chapter concludes with presentation of SDG 6 targets and indicators to quantify the actual gap with respect to 2030 objectives, alongside with initiatives to accelerate SDG implementation and to overcome financing challenges.

Second part discusses the role of desalination as a response to the increasing water supply/demand gap. A brief analysis of the landscape in the desalination market is provided. Then, the interest switches on technological evolutions that occurred in the sector, with particular attention to energetic consumption and environmental impact. Finally, the economics of desalination are analysed in detail to determine the structure of desalination costs.

The third chapter starts by remarking the benefits of the Reverse Osmosis technology, which is the most mature and adopted in the desalination market. Then, after a short introduction of procurement models used for desalination projects, the OSMOSUN case study is presented.

After a description of the company, the strategic analysis carried out allows to appreciate how, thanks to a low-carbon solar desalination technology, a small and innovative company is able to enter in the desalination market by combining contribution towards SDG 6 objectives and attention to environmental impact and climate change action.

The final chapter concludes by considering the buy-side in water-related projects. It begins with a theoretical review of water value and water pricing, alongside with some examples from real projects. At his core, this part is designed to show which type of investors are suitable for different types of projects. The attention is put on particular financing schemes, namely Public – Private Partnerships and blended finance arrangements.

To provide a better comprehension of the topic, a pool of SDG-oriented investors is investigated, allowing to elaborate on how and where they invest and how they can cooperate with public institutions to bridge the funding gap towards 2030 SDG goals.

1 – SDG 6 AS A RESPONSE TO WATER CRISIS

1.1 – WATER IN THE WORLD TODAY

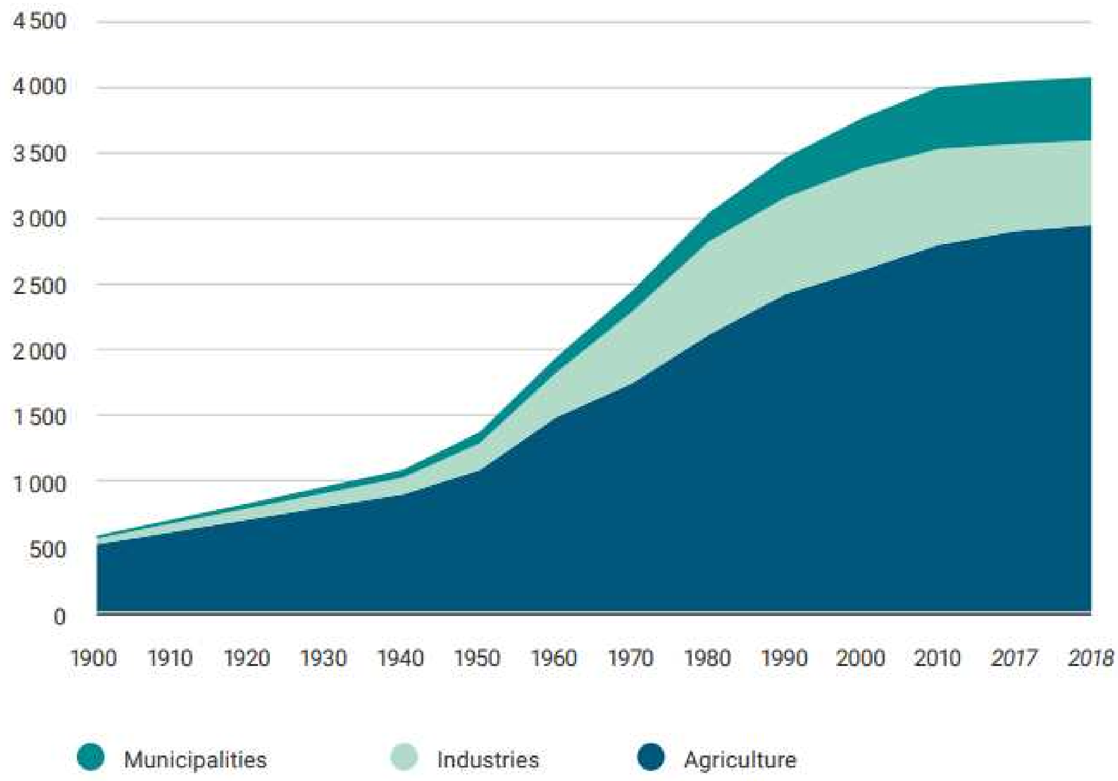
Water covers more than 70% of the Earth's surface and it is therefore one of the most abundant natural resources in our planet. However, the world is nowadays facing an unprecedented water crisis which is difficult to reverse since it is caused by multiple long-term factors. This problem calls for immediate action, in order to mitigate the life-threatening consequences of water scarcity and guarantee universal access to water to everyone in the world.

Water is in fact a scarce resource. This may sound paradoxical, but it is sufficient to take a look at the main figures to recognize the matter immediately. Even though water covers more than 70% of our planet, 97.2% of this water is salty. Only 0.7% is accessible for the needs of human activities, the rest mainly corresponding to ice caps or being highly polluted. For the accessible part, it is constituted by groundwater which represents approximately 0.65%, the balance of 0.05% being surface water, namely lakes and rivers.

Since the vast majority of total water is unavailable for human needs, it is crucial to emphasize the way in which the available portion is used. Conventionally, water use is classified in three distinct categories: agricultural, industrial and domestic.
Globally, water use for agriculture accounts for 70% of the total, most of which is used for irrigation. Industrial use of water presently accounts for 20% of the total: energy production is responsible for 75% of the industry total, while manufacturing covers for the remaining 25%. Domestic global water use represents the remaining 10% of the overall use of water.

Over the last 40 years, water use has been increasing by roughly 1% per year (AQUASTAT, n.d.). The increase comes mainly from middle and lower-income countries, and in particular from emerging economies (Ritchie and Roser, 2017). Regions with the largest water withdrawals per capita have been Northern America and Central Asia. Taking a look at the most recent years covered by data (2010-2018), we note that both agricultural and municipal withdrawals increased. On the other hand, industrial withdrawals decreased by 12%, mainly due to reductions in withdrawals for thermal power production, as cooling processing, one of the most water-intense activity, has become more water-efficient (FAO, 2022).

Figure 1.1: Evolution of global water withdrawals, 1900–2018 (km³/year)



Source: FAO, AQUASTAT.

These aggregate figures mask important local and regional differences which reflect the variety of needs in different areas of the world; in Europe, agriculture represents only 30% of withdrawals, municipalities 26% and industry 44%, whereas in South Asia, the respective figures are 91%, 7% and 2% (FAO, 2022). Even though estimates about future evolution of water demand remain quite uncertain, the real growth will be highly dependent upon whether or not measures to improve water use efficiency are implemented across these different sectors.

Water demand by 2050

Global population growth, economic development and changing consumption patterns represent the main determinants of water demand evolution. From historical data it is known that global water demand has increased by 600% over the past 100 years, which corresponds to an annual increment rate of 1.8%. The present annual growth rate is estimated to be lower, but this figure may be optimistic (Boretti, Rosa, 2019).

Indeed, future trends in demand are difficult to predict accurately. Overall global demand for water will continue to grow at an annual rate of about 1%, resulting in an increase ranging from 20% to 30% by 2050. If these estimates were to be true, the global water demand for all uses, presently about 4,600 km^3 per year, will be quantifiable in 5,500 to 6,000 km^3 per year.

Furthermore, water demand is expected to increase in absolute value in all the three components. Industrial and domestic demand will grow faster than agricultural demand; nevertheless, demand for agriculture will remain the largest (Burek et al. 2016).

The sharp increase in water demand for all types of use is difficult to satisfy and might lead to situations where choices about water allocation need to be made, especially in those areas where scarce water resources combine with a fast-growing population. There are already examples in this sense: shifting resources from agriculture to urban centres has become a common strategy to meet freshwater needs in growing cities. The reallocation of water from agriculture has been generally successful in terms of meeting the demands of growing cities. On the other side, from an agricultural/rural perspective, negative consequences have been observed as less water is available for irrigation, leading to reduced food security and lower farmer livelihood incomes.

In fact, urban water demand is projected to increase by 80% by 2050 (UN, 2023). This is due to the expansion of water supply (and to a lesser extent sanitation) services and is therefore faster in regions where efforts are being made to address lower levels of existing provision.
All regions in the world are expected to show an increase in water demand, except for Western Europe, which is predicted to remain more or less at the same demand level mostly because of its stagnating demographic trend. The greatest increment, 300%, will occur in Africa and Asia; Central and South America will also experience a very significant growth.

1.2 – CLIMATE CHANGE IMPACT

Water demand around the world is surely going to grow dramatically, even if the most conservative assumptions on the main causes (i.e. population growth) are adopted; the same doesn't apply to water supply. Freshwater is a finite resource and its supply relates to the healthy operation of the water cycle. The water cycle refers to the regeneration process of freshwater through the continuous process of evaporation, precipitation, and runoff. Any disturbance of the water cycle will impair the regenerative ability of water.

Water availability is threatened by multiple factors: in this context, a major role is played by climate change, which is likely to increase the frequency, intensity, and severity of extreme weather events like floods and droughts, not to mention the impact on rising sea levels and shrinking ice fields. All of these elements affect the water cycle and result in water being more scarce, more unpredictable and more polluted (UN, n.d.).

The problem of water scarcity can be analysed under three different perspectives: physical, economic, and institutional (UNESCO, 2016).

- **Physical scarcity** refers to water scarcity caused by uneven precipitation in different regions in the world. Some regions may have seasonal rains that receive abundant rainfall throughout the year, while others may have precipitation concentrated in a few months during the wet seasons, the other seasons being relatively dry. This is the case in most of the countries in Asia. Other regions such as central Australia, North Africa, and the Middle East just do not receive enough rain. Additionally, the impact of climate change may have significant effects on the water cycle in terms of precipitation and evaporation patterns.
- **Economic scarcity** refers to water scarcity as a result of insufficient or ineffective infrastructure in the delivery of freshwater for human consumption. This may be due to financial or technical restraints that have hindered the supply of water in some regions, particularly in Africa. Some regions may be so remote that delivery networks are not available.
- **Institutional scarcity** refers to water scarcity when organizations fail to ensure reliable, secure, and equitable supply of water to users.

Therefore, water scarcity is a worldwide problem and is a result of a combination of hydrological irregularities and high human use as a consequence of rapid population growth and urbanization. More water is required for the production of goods and services to satisfy the demand for food and products in cities. UNESCO (2016) further reveals that in 2014, 3.9 billion people (54%) of the global population lived in cities; by 2050 two-thirds of the global population will be living in cities (Ding, Ghosh, 2017).

Water stress and availability

As we have seen, we are in a context of strong growth in water demand – in industry, agriculture and by the general public – which is not supported by a commensurate increase in water supply for human needs. This mismatch is defined as "water demand/supply gap," which can lead to water shortages if no measures of correction are adopted.
In general, water stress can be defined as "the withdrawal of too much fresh water from natural sources compared with the fresh water available." This phenomenon is strengthening and progressing geographically and if unmitigated it can lead to water scarcity.

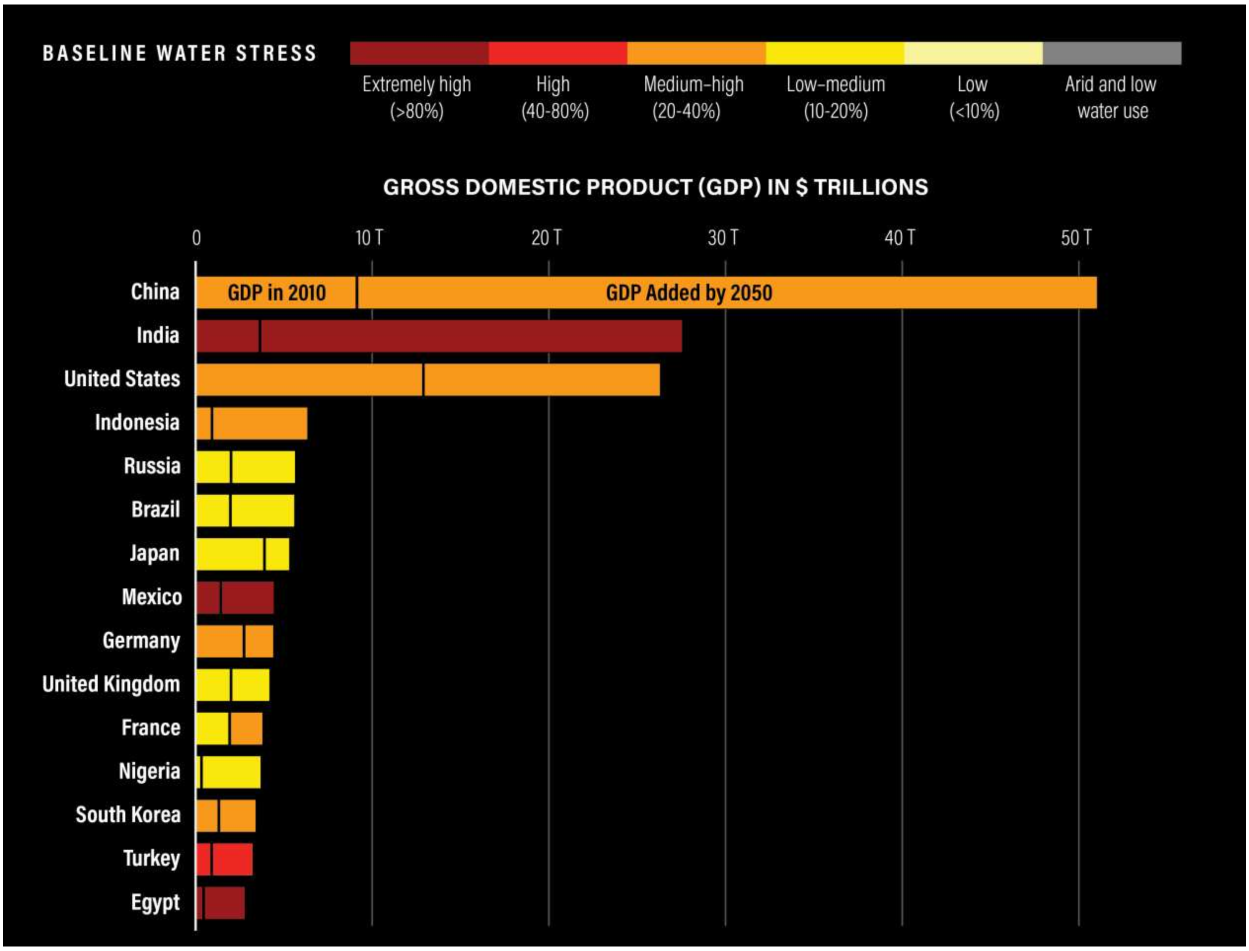
Water scarcity is becoming endemic as a result of the local impact of physical water stress, coupled with the acceleration and spreading of freshwater pollution. Climate change will increase seasonal water scarcity in regions where it is currently abundant such as Central Africa, East Asia and parts of South America. In those areas where water supply is already insufficient, such as the Middle East and the Sahel[1] in Africa, the situation is expected to become even more dramatic. On average, 10% of the global population lives in countries with high or critical water stress; at least 50% of the world's population (around 4 billion people) live under highly water-stressed conditions for at least one month of the year. By 2050, desertification alone will threaten the livelihoods of nearly 1 billion people in about 100 countries (Mazzega, Cassignol, 2020). Low-, middle- and high-income countries all show signs of risks related to water quality. Poor ambient water quality in low-income countries is often related to low levels of wastewater treatment, whereas in higher-income countries runoff from agriculture is a more serious problem. However, water quality data remain sparse, due in large part to weak monitoring and reporting capacity. This is especially true in many of the least developed countries in Asia and Africa (UN, 2023).

[1] The term "Sahel" identifies the semiarid region of western and north-central Africa extending from Senegal eastward to Sudan.

Economic consequences of water crisis

Every region in the world is to some extent impacted by the water crisis. World's leading institutions need to act as a bridge between countries and coordinate a timely and well-executed response; otherwise, monetary costs will be huge. Water scarcity, exacerbated by climate change, could cost some regions up to 6% of their Gross Domestic Product (GDP) by 2050 due to water-related impacts on agriculture, health and incomes, potentially spurring migration and even conflict (World Bank, 2016). Data available from AQUEDUCT show that by 2050 31% of global GDP, which is estimated to be about $70 trillion, will be exposed to water stress. For reference, in 2010 24% of global GDP was affected, corresponding to $15 trillion. Some of the biggest economies in the world are also among the most water stressed countries and half of the exposed GDP in 2050 will be generated from only four countries: India, Mexico, Egypt and Turkey (World Resource Institute, 2023).

Figure 1.2: 15 largest GDPs by 2050 and baseline water stress



Source: World Resources Institute, Aqueduct.

1.3 – SDG 6

In 2015, the "2030 Agenda for Sustainable Development" was launched with the goal to end poverty and set the world on a path of peace, prosperity and opportunity for all on a healthy planet. The 17 Sustainable Development Goals (SDGs) represent the pillars that will guide the transformation of the financial, economic and political systems that govern our societies today to guarantee the human rights of all. They require immense political will and ambitious action by all stakeholders. As for now, global efforts have been insufficient to deliver the changes required, jeopardizing the agenda's promise to current and future generations (UN, 2020).

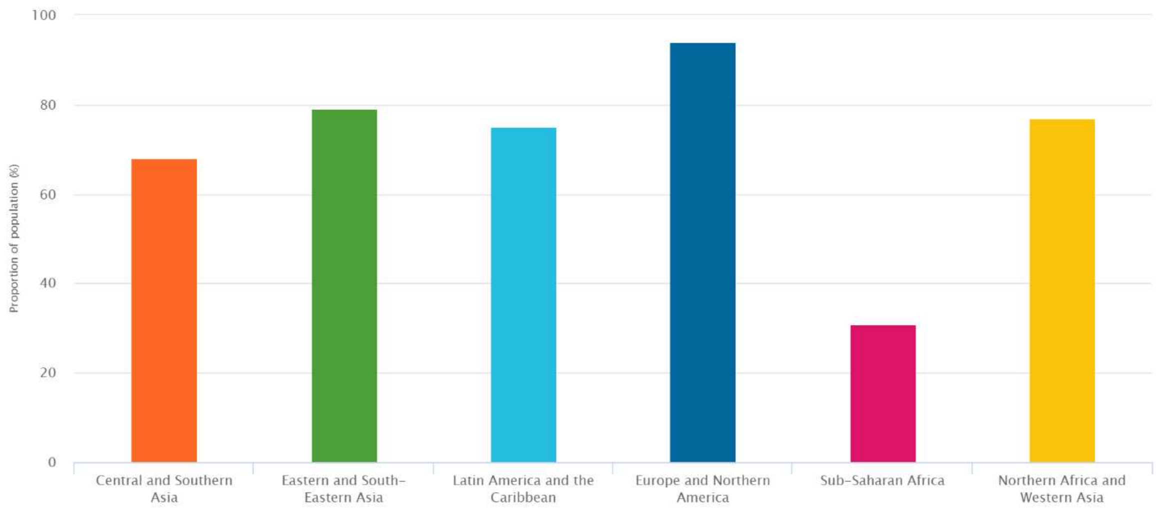
Sustainable Development Goals are very broad in scope and they address various matters, such as ending poverty, guaranteeing education and gender equality, ensure access to clean energy and responsible consumption and production patterns. In particular, SDG 6 addresses water-related issues and establishes the purpose to "ensure availability and sustainable management of water and sanitation for all".
It consists of 6 technical targets (targets 6.1–6.6), 2 means of implementation targets (targets 6.a and 6.b) and 11 indicators.

Billions of people lack access to safe water and sanitation, while the quality and quantity of water resources continue to degrade. Water quality is a major area of concern, with 44 percent of household wastewater not treated and over 3 billion people exposed to potential health risks from unsafe water. The situation varies significantly for different parts of the world and in relation to different targets and indicators, with, in general, poorer and drier regions and countries showing greater water stress. However, some issues such as water quality and the decline of water-related ecosystems are universal and affect richer and poorer countries and regions alike. In the following paragraphs, SDG 6.1, 6.2 and 6.4 are better explained, in order to get a clear picture of the progresses that need to be made to achieve 2030 targets.

SDG 6.1

"By 2030, achieve universal and equitable access to safe and affordable drinking water for all". To track progress towards the target, indicator 6.1.1 monitors the proportion of population using safely managed drinking water services.

Figure 1.3: Proportion of population using safely managed drinking water services (2022)



Sources: WHO, UNICEF.

Between 2015 and 2022, the proportion of the world's population with access to safely managed drinking water services increased from 69% to 73%; this progress means that during this period nearly 700 million people gained access to this essential service.

However, as the graphic above displays, there are stark regional disparities. In particular, sub-Saharan Africa is far behind the rest of the world: only 25% of the population has access to basic hand-washing facilities. As the graphic evidence, there is a huge gap with all other areas of the world: the second-worst region is Central and Southern Asia at 68%. Latin America and the Caribbean, Northern Africa and Western Asia and Eastern and South-Eastern Asia show similar levels of access to drinking water services, which is around 75% to 80% of the population.

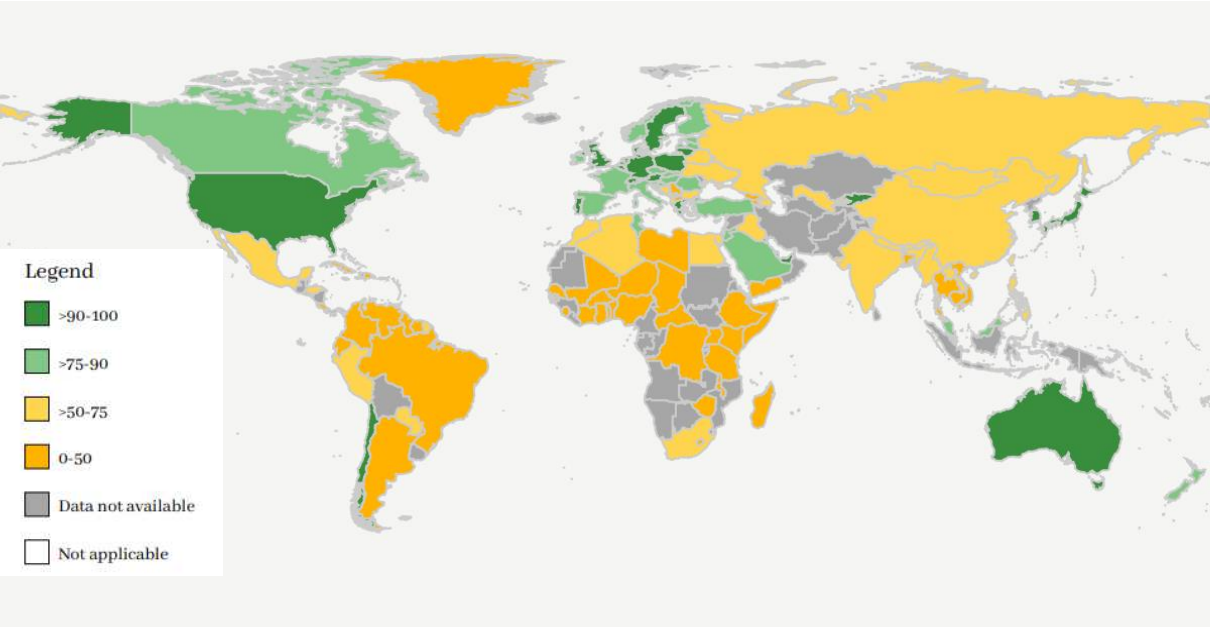
In the period considered, coverage has increased in most SDG regions, but it has stagnated in Europe, North America Latin America and the Caribbean. At current rates of progress, the world will reach only 77% coverage by 2030, leaving 2 billion people without safely managed services. Achieving universal access to safely managed drinking water by 2030 will require on average a sixfold increase in current rates of progress. This also includes a substantial increase in current levels of investment.

On aggregate, 2.2 billion people lack access to drinking water services free from contamination when they are in need. In rural areas, the number of people lacking safely managed drinking water decreased from 1.5 billion in 2015 to 1.3 billion in 2022. However, in urban areas, over the same period, it increased from 784 million to 857 million, thus highlighting the challenge of keeping up with urban growth.

SDG 6.2

SDG target 6.2 states that: "By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations". To track progress towards the target, indicator 6.2.1a monitors the proportion of population using safely managed sanitation services.

Figure 1.4: Proportion of population using safely managed sanitation services (2022)



Sources: WHO, UNICEF.

As of 2022, 57% of the world's population used a safely managed sanitation service. Since 2015, 902 million people have gained access to safely managed sanitation. Approximately 1.5 billion people still lacked basic sanitation services in 2022 – of which two out of three people lived in rural areas. In 2022, only 9 countries had achieved universal access to safely managed services. At the current rates of progress, the world will reach only 65% coverage by 2030, leaving 3 billion people without safely managed sanitation services (UN, 2023).

SDG 6.4

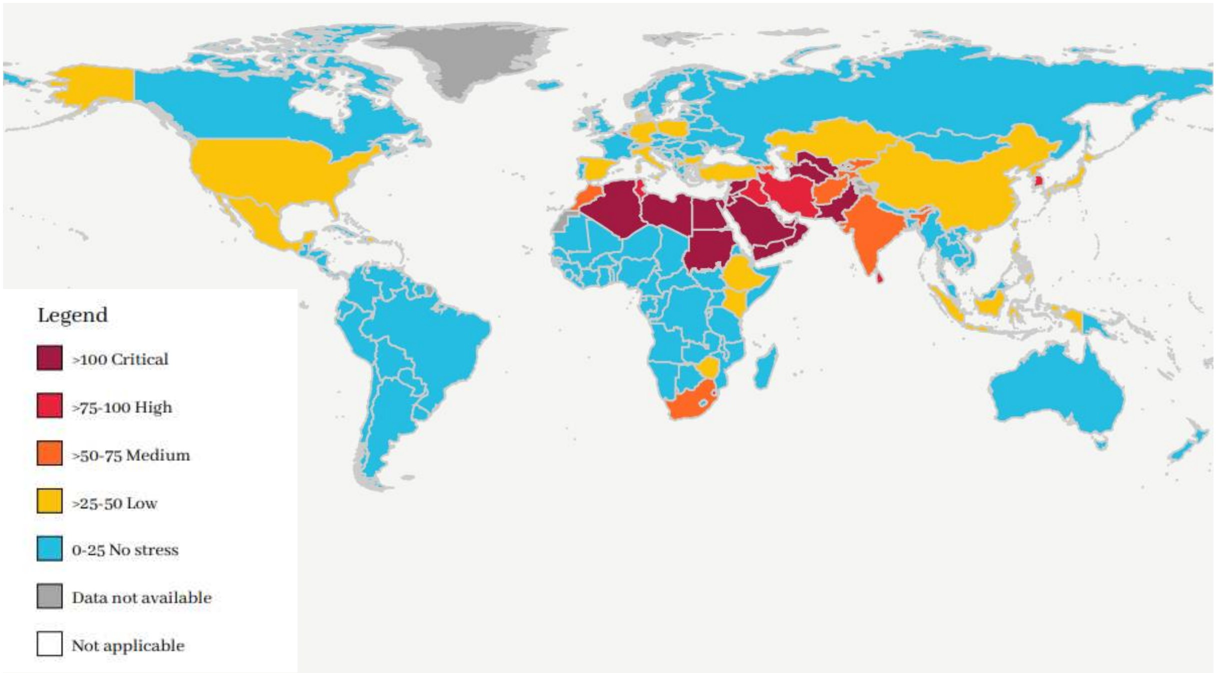
SDG target 6.4 is: "By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity".

To track progress towards the target, SDG indicator 6.4.1 monitors the change in water-use efficiency over time, measured as the ratio of dollar value added to the volume of water used.

Improving water-use efficiency is one key to reducing water stress. Water-use efficiency worldwide rose 9%, from \$17.4/m^3 in 2015 to \$18.9/m^3 in 2020. It ranges from below \$3/m^3 in economies that depend on agriculture to over \$50/m^3 in highly industrialized or service-based economies. The agriculture sector experienced the greatest increase in water-use efficiency from 2015, compared with the industrial and service sectors. To improve water use efficiency, it is essential to act on multiple levers, such as more efficient irrigation, better agricultural management, tackling leakages in distribution networks and optimizing industrial and energy cooling processes.

As far as SDG 6.4.2. is concerned, SDG indicator 6.4.2 monitors how much freshwater is being withdrawn by all economic activities, compared to the total renewable freshwater resources available.

Figure 1.5: Freshwater withdrawal as a proportion of available freshwater resources (2020).



Source: FAO.

Water withdrawals are defined as freshwater taken from ground or surface water sources (such as rivers or lakes), either permanently or temporarily, and used for agricultural, industrial or municipal (domestic) uses. They are expressed in % as a share of internal (renewable) resources[2]. The Food and Agriculture Organization of the United Nations categorise water

[2] Available renewable water supplies include surface and groundwater supplies and considers the impact of upstream consumptive water users and large dams on downstream water availability.

stress in the following ways: if withdrawals are less than 25 percent of resources then a country has no water stress; 25-50 percent is low stress; 50-75 percent medium; 75-100 percent high stress; and greater than 100 percent is critical stress.

An estimated 18% of the world's total renewable freshwater resources was withdrawn in 2020: according to the water stress categories identified, it is appropriate to say that the world as a whole is not water stressed at the moment; this sounds like good news, but a deeper analysis is required to address this matter. In fact, the trend from 2015 to 2020 is not as reassuring: the indicator 6.4.2 increased by about 1% from 2015 to 2020, suggesting that the level of global water stress is currently rising. Furthermore, this global figure hides regional, national and subnational variations.

As shown, several countries across the Middle East, North Africa & South Asia have extremely high levels of water stress. Many, such as Saudi Arabia, Egypt, United Arab Emirates, Syria, Pakistan, Libya have withdrawal rates well in excess of 100%— this means they are either extracting unsustainably from existing aquifer sources or producing a large share of water from desalinisation.

Most countries across South Asia are experiencing high water stress; medium-to-high across East Asia, the United States and much of Southern and Eastern Europe. Water stress in Northern Europe, Canada, much of Latin America, Sub-Saharan Africa and Oceania is typically low or low-to-medium.

The most recent information available is from 2020 and it is estimated that in that year 2.4 billion people lived in water-stressed countries (level of water stress equal to or greater than 50%), of which almost 800 million lived in high and critically high water-stressed countries (level of water stress equal to or greater than 75%).

SDG 6 Acceleration Framework

The progress monitor clearly shows that there is still lots of work to do to comply with the goals that should be reached by 2030. The latest evaluation, carried out by United Nations Water in 2021, confirms that overall progress towards SDG 6 is "off track". The Sustainable Development Goals are surely ambitious, and it is always important to remind that the starting point is different for each country. As we have seen, some areas of the world face very critical situations, and despite some improvements have been made, lots of people still suffer from lack of essential water services.

There are several bottlenecks impeding greater progress. Policy and institutional fragmentation between levels, actors and sectors means that decisions taken in other sectors (e.g. agriculture, energy, health, environment) often do not consider the associated impacts on water availability and water quality, and that issues do not receive the necessary political attention. Funding gaps and fragmentation impede progress across levels, while data and information too often are not available or not shared between sectors and across borders to effectively inform decision-making. Meanwhile, gaps in institutional and human capacity, especially at the level of local governments and water and sanitation providers, slows implementation of SDG 6 along with outdated infrastructure and governance models.

To overcome such challenges, the international community committed to improve its support to achieve SDG 6 on water and sanitation through four action pillars, which are explicated inside the "SDG 6 Global Acceleration Framework". These four pillars are:

1. **Engage**: provide swift responses to country requests through leveraged expertise and mobilization.
2. **Align**: coordinated approaches across sectors and actors through unified strategies and initiatives;
3. **Accelerate**: unlocked bottlenecks through five accelerators;
4. **Account**: strengthened accountability through joint review and learning.

For our purposes, we focus on the accelerate pillar, where emphasis is put, among other topics, on the importance of "optimize financing for water and sanitation" in supporting the timely execution of projects designed to achieve SDG 6 objectives.

The SDG 6 Global Acceleration Framework states that funding gaps represent one of the main constraints that hinder progress; at the same time, it remarks that "existing funding from different sources is often uncoordinated among donors or sometimes even counterproductive". The document concludes that "improved targeting, better utilization of existing resources including harnessing of synergies between different SDGs, and mobilization of additional domestic and international funding for the water sector, together with innovative financing including blended finance and smart water and sanitation investments, is required to catalyse efficient service delivery and implementation".

Financing SDG 6

The water sector requires a considerable amount of financing, with estimates ranging from $182 billion to $664 billion annually (Rozenbery and Fay, 2019). This gap includes various areas such as water supply and sanitation ($116 billion to $229 billion) flood protection ($23 billion to $335 billion per year) and irrigation ($43 billion to $100 billion per year), as well as funding for the implementation of water resources management. Estimates indicate that to achieve SDG 6, over $1 trillion will be needed per year, which represent 1.2% of global GDP (Strong et al., 2020).

The water sector provides benefits both to public and private operators. However, the main constraint is represented by the revenue streams generated from investments, which make it difficult to obtain an acceptable return on the capital deployed. Because of this matter, water-related investments are often undervalued, leading to a lack of well-prepared bankable projects and sustainable financing models. According to the Sustainable Development Goal 6 Report on Water and Sanitation (2023), the following are some of the main reasons limiting the development of sustainable financing models:

- Weak enabling environment for investment;
- High initial investment is required to build water infrastructures;
- Investment payback period is usually long, while commercial investors focus their attention on short-term horizons;
- High transaction costs, which are exacerbated by small-scale and fragmented nature of water related investments.
- Lack of data availability and analytical tools to assess the investment.
- Lack of sector-specific knowledge among investors and financiers.

Due to this problems, water-related investments have historically been financed by public budgets, including international transfers, with contributions from water users (e.g. water tariffs). As a measure for this mean of financing, SDG target 6.a measures the amount of water and sanitation-related official development assistance (ODA) included in a government coordinated spending plan. Overall ODA increased from $191 billion in 2015 to $235 billion in 2021. However, focusing on ODA for water, we observe a different trend: since the beginning of the millennium the figure increased steadily, from US$2.7 billion in 2002 up to US$9.6 billion in 2018, then dropping to US$8.7 billion in 2020. Compared to other sectors, these funds represent a minor share of total ODA, with just below 4% allocated to water over the 2016–2020 average (UN,2023).

As far as the private sector is concerned, investment incentives in the water sector are mainly limited by a number of market failures, such as imperfectly competitive markets, externalities and asymmetric information. Furthermore, according to SDG 6 objective “ensure availability of water and sanitation for all”, water is nonexcludable and it is to be considered as a public good, which is a typical reason for market failure.

In addition, various investment barriers slow down the design and implementation of investments or even prevent them from happening at all; they affect both the cost and the risk of the investment. In the water sector, the biggest barriers are market fragmentation, regulatory uncertainty, capacity constraints among public sector promoters, and limited access to finance (European Investment Bank, 2023).

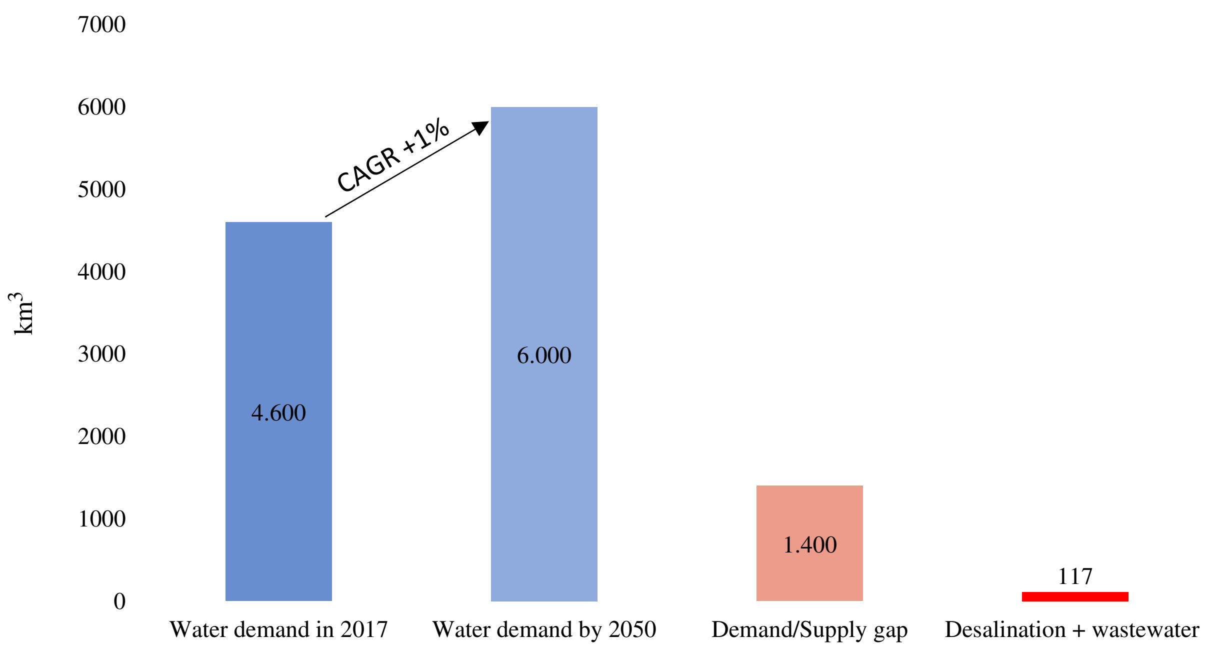
Instead of focusing solely on bankable projects, the priority should be put on creating the necessary enabling conditions to attract investments, and for using grants to establish water and sanitation solutions that can generate at least some of their own financing needs. Successful approaches should be replicated and scaled up, and financial resources redirected to where they are most effective. To address the challenges facing governments, the global development finance architecture needs to be reformed to provide more funding to governments. As suggested by the OECD (Roundtable on Financing Water, 2023), this can be done through enhancing multilateral development banks' efficiency of capital use or extending fiscal space for low-income countries. This should be contrasted with the need for more direct funding for small- and medium-sized enterprises and for redirecting investments or pooling resources to achieve multiple benefits.

2 – DESALINATION TO INCREASE WATER AVAILABILITY

2.1 – WATER DEMAND/SUPPLY GAP INCREASE

The depletion of available resources in many countries, together with population growth and extreme weather events related to climate change, contributes to the overall imbalance between available resources and demand for water: this is the so-called water demand gap. As seen in chapter 1, water stress around the world is increasing, but water availability varies greatly among different regions. Water is in fact unevenly distributed around the world, with nearly 60% of renewable natural freshwater resources present in nine countries: Brazil, Russia, Indonesia, China, Canada, United States, Colombia, Peru and India. On the contrary, almost zero resources are available in countries like Kuwait, Bahrain, the United Arab Emirates, Malta, Libya, Singapore, Jordan, Israel and Cyprus. This imbalance exacerbates the water stress: on one side, the natural distribution of water is concentrated in very few countries; on the other side, some of the fastest-growing populations in the world live in areas with almost no freshwater available.

Figure 2.1: Predicted evolution of water demand/supply gap.



Source: Elaboration on Boretti, Rosa, 2019.

Water withdrawals were 4,600 km^3 per year worldwide in 2017, but this demand is expected to surge up to 6,000 km^3 per year by 2050, driven by the growth of population and the needs for various applications seen in Chapter 1. In a situation of increasing demand for water and strong tension on its availability, new ways to expand the supply are being promoted. Alternative solutions would reduce the gap identified between future water demand and available resources. Two solutions that are currently used worldwide and experiencing strong growth are seawater desalination and wastewater reuse. In 2022, the cumulative and combined capacity of seawater desalination and wastewater reuse worldwide was 117 km^3/year (cumulative over the period 2002-2022), which already represents 8% of the gap with additional demand by 2050 (IDA Desal and Reuse Handbook 2022-2023).

Finding a response to this phenomenon is crucial to guarantee universal water access: global population is growing at unprecedented speed and by 2050 almost 10 billion people will be leaving on earth. This requires implementing effective solutions which can only be obtained by technological progress. So far, two main measures have been adopted to mitigate this crisis: reuse of wastewater and desalination of water, mainly seawater and brackish water.

2.2 – WASTEWATER REUSE

Wastewater can simply be thought as water that has been somehow used and then discharged. Sticking to this definition, it is immediate to say that it is produced every day and that every person in the world contributes to some extent in the quantity of wastewater produced. A more formal definition is provided by the United Nations, which refer to wastewater as “water which is of no further value to the purpose for which it was used because of its quality, quantity or time of occurrence. However, wastewater from one user can be a potential supply to a user elsewhere” (United Nations Statistics Division, 2011).

Wastewater can contain a wide range of biological, chemical and physical contaminants such as heavy metals, microplastics and pathogens. As a consequence, the discharge of untreated wastewater has a negative impact on the environment on multiple levels:

- Algal blooms resulting from excess nutrients in wastewater may threaten life under the sea by reducing light levels and decreasing oxygen available;
- Pathogens in wastewater can contaminate water and cause diseases;
- If used in agricultural irrigation, food safety is at risk and soil is subject to degradation.

Since it comes from human activity, the amount of wastewater produced is related to the global economic growth. Including wastewater reuse in the water supply equation represents a key to build a circular economic model capable of increasing water availability in water-stressed countries or strengthening countries’ self-sufficiency. Additionally, it is a solution that protects nature by limiting the risks of polluting discharges into the environment.

Wastewater reuse refers to the practice of using untreated, partially treated or treated wastewater for resources including potable and non-potable water, irrigation water, nutrients, energy and heat value. Safe wastewater reuse can be obtained when the wastewater is subject to the appropriate level of treatment required to reach the quality standard for the intended purpose.

According to United Nations Environment Programme, types of reuses can be classified in three categories:

- **Non-potable**: Use of reclaimed water not meeting drinking water standards for non-potable purposes. A major example is industrial reuse, where non-potable water can be used to satisfy industrial water requirements. Other potential reuse opportunities for non-potable water include irrigation for municipal parks or golf courses;

On the contrary, potable reuse identifies the “use of high-quality reclaimed water as a water source for drinking water treatment and supply”. Potable reuse can be either direct or indirect:

- **Direct potable reuse** (DPR): The injection of high-quality reclaimed water directly into the potable water supply distribution system, either upstream or downstream of the water treatment plant;
- **Indirect potable reuse** (IPR): Augmentation of natural sources of drinking water (such as rivers, lakes, aquifers) with reclaimed water, followed by precedes drinking water treatment.

Wastewater collection and reuse has the potential to be an effective way to address several sustainability issues, ranging from water scarcity and pollution to climate change adaptation. Wastewater is indeed central in ensuring the health of human beings and ecosystems. This is also recognized in the Sustainable Development Goals: SDG 6.3 relates to improved water quality and includes reducing the proportion of untreated wastewater as well as increasing recycling and safe reuse.

There is an urgent need to change the way in which wastewater is perceived: the point of view should switch from a waste management issue to a valued resource. This change in mentality hasn’t happened yet. Data about wastewater are not encouraging: worldwide, only 4% of wastewater is recycled (Veolia, 2021) and it is a resource most commonly destined for uses other than tap water. High-income countries treat on average about 70% of the wastewater they generate. This ratio drops to 38% in upper middle-income countries and to 28% in lower middle-income countries. In low-income countries, only 8% of wastewater generated undergoes treatment of any kind (European Investment Bank, 2022).

According to this data, what emerges is that wastewater is a resource with an unexploited potential; at the moment, its primary destination of use is agricultural and industrial, while potable reuse is still a very small component.

2.3 – DESALINATION MARKET

Water desalination is gradually emerging as the leading solution to cope with increasing water stress. The progress of desalination to 2050 is difficult to forecast because it will depend both on economic progress and energy-related issues, as well as the pace of technological innovation in the sector. Apart from the discovery of new aquifers, desalination is considered to be the most effective measure to increase water resources. Currently, about 1% of the world's population living in coastal areas is dependent on desalination (Boretti, Rosa, 2019). This solution presents two main obstacles: firstly, it requires significant energy inputs; closely related to that, the energy demand makes it a very expensive alternative.

Market size

There is a growing interest in alternative solutions for producing freshwater, in order to respond to the challenges presented in Chapter 1. It comes with no surprise that the desalination industry has in fact experienced a strong growth over the last twenty years.

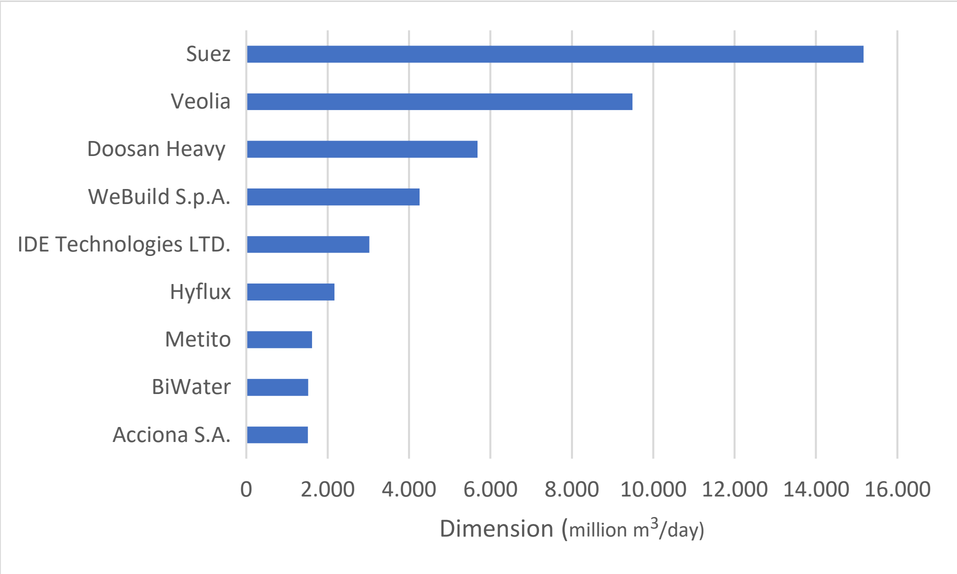
In 2022, the desalination market reached 16 billion euros with annual growth of 5% since 2015. This market growth is correlated with the growing need for fresh water for human activities and with the increase in water stress throughout the world. In the upcoming years, this trend is expected to be confirmed and even speed up due to the worsening situation of water-related issues. For the period 2023 – 2026, the global desalination market Compound Annual Growth Rate (CAGR) forecasts predict an 8% increase (Global Water Intelligence Desaldata, 2022).

Player's size

Desalination plants can be segmented in a variety of ways. A major distinction regards their size: there are about 22,000 plants listed worldwide, which range from very small plants, capable of desalinating less than 1,000 m^3 of water per day, up to much bigger plants with a capacity over 1 million m^3 per day. The latter can be found mainly in the Gulf countries. Even though the desalination industry is experiencing a strong growth, plants composition in terms of size is remaining unaffected.

According to Global Water Intelligence, over the period 2016-2022 projects observed ranged from 1 to more than 900,000 m^3/day with the average project being around 11,500 m^3/day. The market is strongly characterized by medium and small projects, which are defined by a capacity not exceeding 50,000 m^3/day: they represent 96% of desalination projects in 2022, while in 2016 they accounted for 98% of the total.

Figure 2.2: Desalination capacity of major industry players



Source: Elaboration on Eke, et. al, 2020.

The players operating in the industry reflect this characteristic and they are themselves of different dimensions. Thanks to the global nature of the sector, it is possible to identify some key players, which have emerged for more than ten years as undisputed market leaders. In France the two main companies are Engie and Veolia, whose merger with Suez opened up new prospects in the Americas, the Middle East and Europe; Acciona and Abengoa are both based in Spain. WeBuild S.p.A. is an Italian multinational company which is partially owned by the State through "CDP Equity". Outside Europe, two of the most notable companies are IDE Technologies, the Israeli national champion of desalination, and South Korea's Doosan Heavy.

Geographical segmentation

This global crisis requires states to rethink their water policies, which are central to retain sovereignty, ensure resilience against water stress, and preserve stability. In fact, water-stressed countries are more likely to experience instability as water scarcity dramatically increases the chances of conflicts.

Few countries have embarked on the deployment of seawater desalination capacities as part of a strategy which encompasses response to current emergencies but also anticipation of the future needs. Desalination infrastructures thus expanded from 18,000 plants in 2017, generating about 97 million m^3/day, to more than 21,000 in 2022, producing nearly 110 million m^3/day.

Since 2000, global capacity has increased fivefold and allows on a daily basis more than 300 million people to benefit from desalinated water.

The desalination sector is indeed booming. The industry core is located in Middle Eastern countries: this area accounts for almost 50% of global capacity. In the Gulf countries alone, desalination capacity is expected to almost double by 2030, as these countries are aiming to foster their resilience to the high water-stress they are experiencing.

For the majority of Gulf countries, desalinated water is already a crucial resource to guarantee sufficient consumption levels to the inhabitants: in the United Arab Emirates (UAE), 42% of drinking water comes from desalination plants producing more than 7 million m^3/day. In Kuwait it is 90%, in Oman 86%, and in Saudi Arabia 70%. Saudi Arabia's desalination capacity is set to increase from 5.6 million m^3/day in 2022 to 8.5 million m^3/day in 2025, and it will have to cover more than 90% of the country's water consumption.

As mentioned above, almost the totality of desalination plants in the world has a capacity under 50,000 m^3/day. Middle East region, and especially Gulf countries represent an exception where very large plants are used to satisfy population's water demand.

The rise of desalination first in the Gulf can be explained by a relatively low financing cost thanks to the support of local institutions, which are able to finance these mega-projects thanks to special vehicles financed by Sovereign Wealth Funds. Some of the largest Sovereign Wealth Funds in the world belong to Gulf countries, such as Saudi Arabia's "Public Investment Fund", UAE's "Abu Dhabi Investment Authority" and "Qatar Investment Authority" of Qatar. Other elements that play an important role are the low construction cost and most importantly very low energy cost, which represent a major concern for the economic feasibility of these projects. This is made possible due to the abundance of local fossil resources.

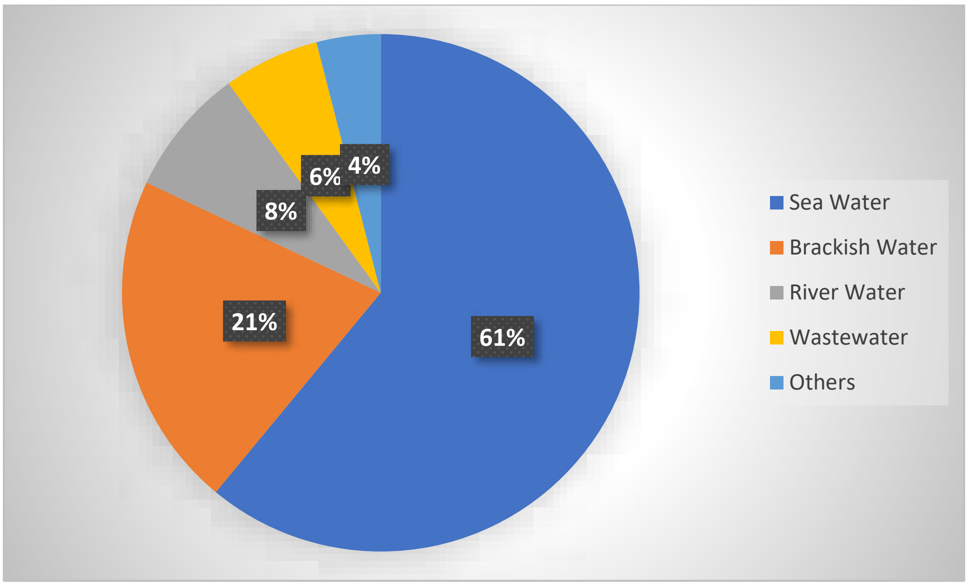
The rise of available solutions to meet different needs is pushing the demand on virtually every continent. A study published by Mazzega and Cassignol in 2022 explains that technological advances and the rise of environmental regulations favouring renewable energies are allowing the democratization of desalination on a global scale.

In Africa, large-scale projects have recently been announced in Algeria and Morocco, countries that had sufficient resources but are now depleting them. Other countries such as Ghana, Senegal and Kenya supply many cities with desalinated seawater. This is also the case for Cairo. In the Indo-pacific region, particularly in China and India, the needs for desalinated water are increasing, driven by growing industries and decreasing available water. In 2020 alone, the construction of more than 35 desalination plants was announced in China, as well as six in the Philippines, and six in Taiwan. In the Americas, the west coast of the United States stands out with important projects in California, and Texas is not far behind. In Latin America, new projects are emerging in Peru and Chile, driven mainly by the needs of the mining industry, while in Mexico the demand for desalinated water notably comes from the population. Finally, island areas stand out for their strong needs for desalinated water: Cebu in the Philippines, Cape Verde, the Canary Islands and the Maldives are increasingly using desalination capabilities.

2.4 – ENERGETIC CONSUMPTION

The principle of desalination is to remove salts from sea water or brackish water, to produce fresh water. Several technical solutions allow desalination: the most used worldwide are thermal technologies and membrane technologies. Desalination plants generally use lots of electricity, with variations depending on multiple factors including the technologies employed and the feed water, which is the water that goes through the treatment process.

Figure 2.3: Feed water by type



Source: **Jones, 2019.**

Amount of energy required to produce 1 m^3 of drinking water has a direct impact on environment. A more efficient process means lower carbon emission. Surface water treatment is the least energy intensive since most of time it is available near to the delivery point. Ground water treatment utilizes the most energy in the pumping process, depending on water table depth. Brackish water treatment requires significant energy depending on composition and concentration of salt. Seawater treatment is not only highly energy intensive because of feed water quality but it also impacts environment in a number of ways:

- Energy utilized in the desalination processes increases environmental pollution;
- Concentrated and hot brine can affect marine life;
- Contamination of water aquifers occurs due to pretreatment chemicals and corrosion materials.

Seawater and brackish water remain the most frequently used feed water sources for desalination because these sources are available in exhaustible amounts in seas, oceans, and large inland lakes. Most desalination plants focus especially on seawater because it allows to achieve a production rate close to their installed capacity (Eke et.al, 2020).

Technologies in the market

Technology adopted in the desalination process has huge implications for the amount of energy used: the first-generation desalination plants employed thermal technologies and were more frequently installed in the past. Throughout the 20th century, hundreds of thermal distillation desalination plants were built around the world. Despite their relative high energy intensity, many of these first-generation desalination plants are still in use today. The second generation was born in 1959, when two researchers at UCLA developed the first Reverse Osmosis membrane.

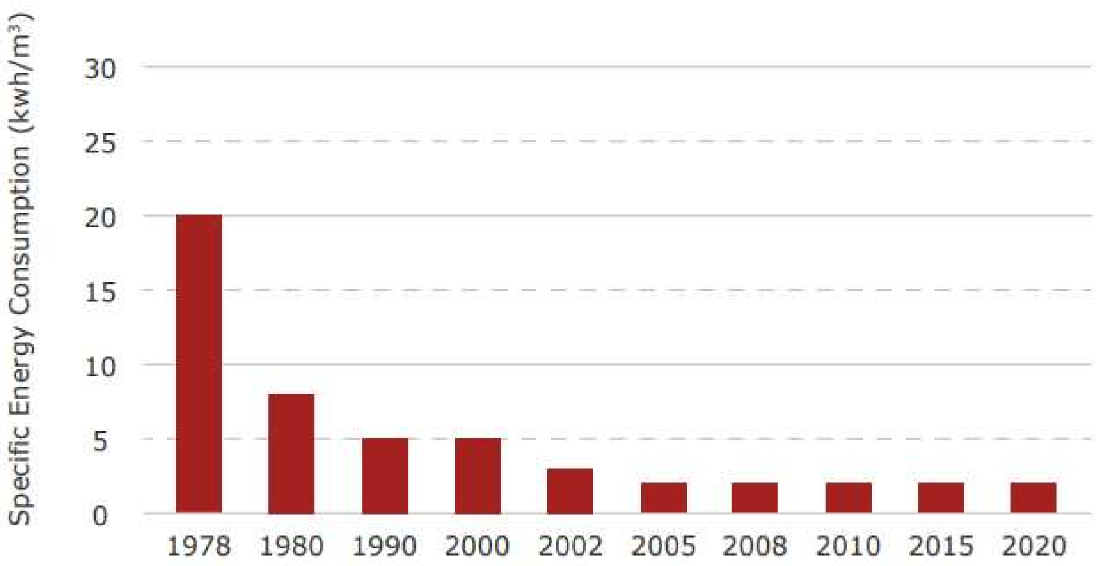
Thermal distillation is a phase separation method. This means that seawater is heated until it vaporizes; water in its gas phase is then cooled down and returns to liquid phase through condensation: since salt has a different boiling point, it does not vaporize, and the result of the process is pure H_2O. An article published by Danfoss (2021) briefly illustrates the main thermal technologies:

- **Multi-stage flash** (MSF): Seawater is partially evaporated (flashed) in a sequence of stages, each with its own pressure and boiling point. MSF plants operate at approximately 20 – 27 kWh/m^3;
- **Multiple-effect distillation** (MED): MED plants also consist of a series of stages, or “effects.” In MED plants, each effect contains steam-heated tubes to evaporate a portion of the feed water. More energy-efficient than MSF, MED plants operate at approximately 14 – 21 kWh/m^3 of distilled water;
- **Mechanical vapor compression** (MVC): MVC plants use pressure turbines to compress water vapor to create additional heat and vapor. Employed primarily in thermoelectric and medium-sized plants, MVC is the most energy-efficient form of thermal distillation, requiring between 7 – 12 kWh/m^3 of distilled water.

Generating the heat to boil seawater requires lots of energy. Over the years, efficiency has significantly improved: the most energy-efficient MVC plants using just a quarter of the energy required by the least energy-efficient MSF plants. Yet, this technology remains very costly in terms of energy and emissions.

Reverse osmosis is the most widespread membrane process nowadays. The natural phenomenon of osmosis consists of balance of forces between two liquids, which allows a weakly concentrated liquid to cross a membrane to dilute a more concentrated medium. Reverse osmosis is possible by using high-pressure pumps to force seawater through a semi-permeable membrane, allowing the solvent molecules, H_2O, to pass through the membrane but not the dissolved salt or other contaminants. RO is a physical process that involves no phase change and, in contrast to thermal distillation, does not require the heating of water. The idea of filtrating water is not new, but while filters separate even very tiny particles from water, they cannot remove dissolved chemicals. Reverse osmosis produces available freshwater because it acts at a molecular level and it not only retains salts, but also retains organic matter, viruses and bacteria, pesticides and herbicides.

Figure 2.4: Specific energy consumption in Reverse Osmosis over time.



Source: Danfoss, 2021.

The specific energy consumption (SEC) of RO membranes dropped precipitously in the late 1970s with the introduction of thin-film composite technology. Since then, innovation has reduced membranes' SEC even further, to about one-tenth of the first generations of cellulose acetate membranes. The main driver of RO energy consumption is high-pressure generation which is required to force seawater through the membranes. Here, both energy recovery devices (ERDs) and pump efficiency play important roles.

The SEC of the today's most energy efficient SWRO plants using the best RO membranes, less than 2 kWh/m^3, is close to the thermodynamic limit of 1 kWh/m^3. Still, room for improvement remains, particularly in the desalination of seawater, for which the energy demand is still significantly higher than the energy consumption of non-saline surface water treatment technologies.

Reverse osmosis technologies nowadays represent the majority of new installations, accounting for about 69% share of the installed desalination capacity; besides, almost all of the new contracts are awarded with membrane desalination technologies in mind. There are 14,365 existing RO plants. MSF and MED account for 17% and 7% of the current installed desalination plants worldwide.

2.5 – ENVIRONMENTAL ISSUES

Greenhouse gas

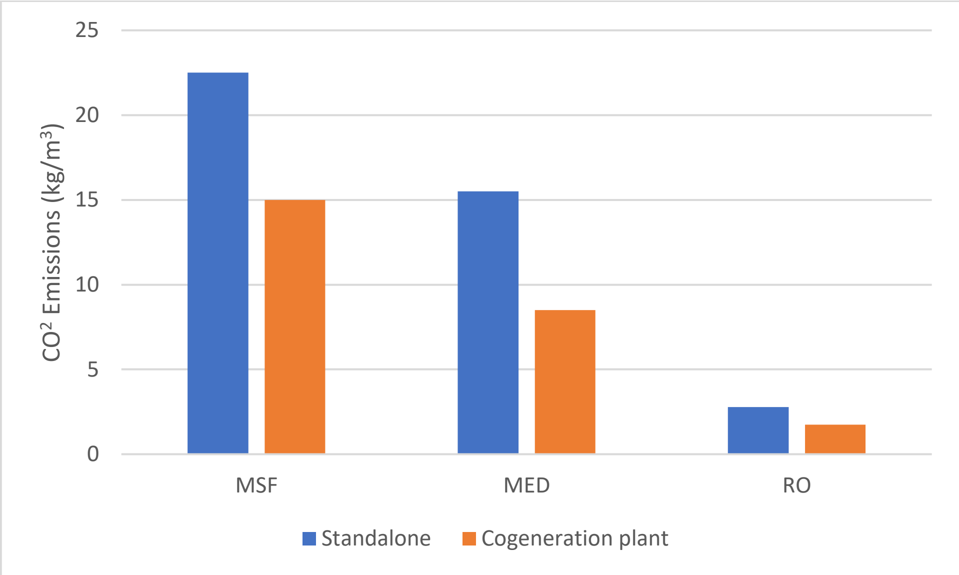
Greenhouse gas represent one of the main contributors to global warming. In the most recent years, the need to reduce greenhouse emission has been recognized worldwide and international agreements have been signed. In particular, the Paris Agreement requires signatory countries to embark on a path to reduce greenhouse gas (GHG) emissions, and more than 130 countries have committed to achieving carbon neutrality by 2050. In December 2023, the COP28 meeting held in Dubai ended with a final resolution which states the need to "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science".

This means that the model of desalination based on plants boosted by fossil fuels is no longer sustainable. Up to now, desalination plants in the Middle East have largely benefited from an energy mix based on fossil fuels that permit cheap desalination. For example, electricity consumption for water desalination increased threefold in Saudi Arabia during the period 2005-2020, reaching about 6% of the kingdom's total electricity consumption in 2020 (Mazzega, Cassignol, 2022).

The expected increase in desalination capacity will therefore boost electricity demand and associated GHG emissions if the electricity mix remains largely dominated by hydrocarbons. The demand for gas and oil to produce this electricity would also increase. Water desalination is an industry that emits a significant amount of GHGs, as desalination processes are very energy-intensive, with energy consumption depending on the method used. The energy consumption associated to each technology can be translated into CO_2 emissions.

Shahzad et. al (2017) quantify the CO_2 production of various technology both as a standalone operation and as a cogeneration operation with steam power plants.

Figure 2.5: CO_2 emission of different technologies



Source: Personal elaboration on Shahzad et.al, 2017.

The graphic above reports the midpoint range of carbon emissions for each technology. As it is expected, the emissions associated to thermal technologies are much larger than the ones produced by reverse osmosis. Cogeneration systems are designed to produced both electricity and potable water and allow to obtain several benefits, including reduced desalination cost and reutilization of low-grade waste heat to reduce specific energy consumption (Shahzad et.al, 2017). Overall, energy consumption varies according to the energy mix, the type of plant and its size, it can nevertheless be estimated that at least 120 million tons of CO_2/year are generated by desalination sectors each year (Mazzega, Cassignol, 2022). According to World Bank (2019), the volume of GHG emissions could reach 400 million tons of CO_2/year by 2050 without a paradigm shift in the technology adopted. It is worth mentioning that crude oil also contributes four times more to GHG emissions than other fossil fuels used for desalination.

Brine discharge

The management of brines represents another major issue for the expansion of water desalination. After the desalination process, two products are obtained: the permeate (desalinated water) and the concentrate or "brine". This byproduct is to be considered as wastewater because it contains high levels of salt and also chemical products used in the pre-treatment phase. It is unsuitable for any agricultural, industrial or municipal use and it is often times released into the sea, but also in river, lakes and wetlands (United Nation Environment

Programme, 2019). When released into the sea, 80% of brine discharge occur within 10 km of coasts and fall to the seabed. Since it is a highly polluting it heavily impacts the environment, depending on marine flows and the specific hydrological characteristics of the area.

Brine production follows closely the geographical patterns of the desalination market. In fact, more than 55% of brines are produced by Saudi Arabia, the UAE, Kuwait and Qatar. The explanation is provided not only by the number and size of plants located in these countries, but also by the technology used. Furthermore, after the reverse osmosis process brine is rejected at ambient temperature, without thermal pollution as in thermal technologies.

In fact, each desalination plant has a different water recovery efficiency, which mainly depends on technology used and quality of feedwater. Jones et. al (2019) propose a simple equation to calculate brine production, which considers both recovery ratio and the treatment capacity of the plant.

$$Q_b = \frac{Qd}{RR} * (1 - RR),$$

where Q_b is the volume of brine produced, Q_d is the desalination plant treatment capacity and RR is the recovery ratio.

It is observed that, independently from the technology employed, the recovery ratio increases as the feedwater quality increases (or the salinity decreases). Different combinations of feedwater-technology are provided: Seawater (SW) – Reverse Osmosis (RO) operates at a substantially lower recovery ratio (0.42) compared to Brackish Water (BW) – Reverse Osmosis (0.65) and River Water (RW) – Reverse Osmosis (0.85). Similarly, BW – NanoFiltration (NF) (0.83) is substantially more efficient than SW – NF (0.69).

Individual desalination technologies are also associated with vastly different recovery ratios. Thermal technologies (e.g. MSF, MED) are typically associated with much lower recovery ratios than membrane technologies like reverse osmosis and nanofiltration. For example, MSF displays a recovery ratio which is about the half of RO for all feedwater types. Finally, the water recovery ratio of other membrane technologies like NanoFiltration and ElettroDistillation (ED) is substantially higher than RO across all feedwater types.

Worldwide, the amount of brine produced is about 50% larger than the amount of desalinated water. In the Middle East, brine produced almost doubles the desalinated water, which indicates a Recovery Ratio around 0.33. In almost all other regions, recovery ratio is around 0.50 (1 liter of brine produced for every liter of desalinated water) or higher; this is the case of North

America, where recovery ratio is 0.75, meaning substantially lower volume of brine than the amount of desalinated water produced.

A World Bank study carried out in 2019 to analyze the environmental impact of desalination estimates that, should no measure be adopted to make the process more sustainable, the annual rate of discharged brines could reach 240 km^3 by 2050, in comparison to the 40km^3 of present days. Since the use of desalination solutions is increasing at an unprecedented pace, addressing these challenges is a primary objective to avoid significant increase in emissions: a major contribution could come from greener electricity sources.

Potential for Renewable Energies

Pursuing the objectives set up by international agreements requires the construction of desalination plants powered by low-carbon energy sources (fields of solar panels, concentrated solar power, wind turbines, wave energy, or even nuclear power), possibly with combined cycle power plants for back-up capacity. The aim is therefore to decarbonize electricity mixes to ensure plants provide low-carbon water supplies. Several Gulf countries are beginning to mobilize renewable energy sources, such as the Al Khafji reverse osmosis plant in Saudi Arabia, which desalinates 60,000 m^3 every day, and which is powered by photovoltaic panels. In addition, there are also power stations that operate using wave and geothermal energy.

Renewable energy sources are not often used in desalination worldwide: nowadays, renewable powered desalination plants produce only 1% of the world's desalinated water. the major benefits associated to renewable desalination processes relate to freshwater availability and environmental and energetic sustainability. The potential of solar power is particularly interesting because some of the most water-scarce areas in the world are also the ones in which solar activity can be fully exploited to generate energy, like in the case of photovoltaic solutions.

Shahzad et. al (2017) report that, among renewable energy sources, solar photovoltaic (PV) is leading with 43% utilization, followed by solar thermal (27%), wind (20%) and hybrid (10%). The major drawback with PV utilization is the availability and area required for installation: operating a small RO plant with a capacity of 1 m^3 /day (assuming a total specific energy consumption of 8 kWh/m^3), roughly requires a PV installation of 26.5–28 m^2. PV-SWRO have advantages of continuous operation if they are integrated with cogeneration plants grid. Since solar energy is intermittent, PV can supply power to cogeneration plants grid at daytime; energy is typically stored in batteries and allows SWRO to continue at night by tapping power from cogeneration plants grid.

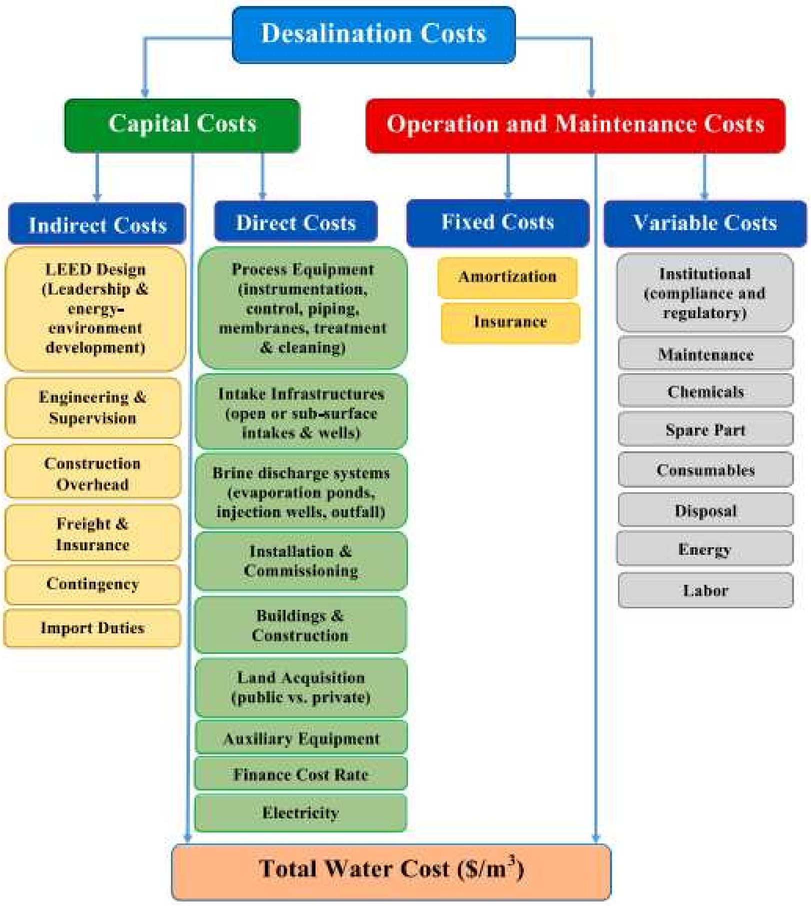
2.5 – ECONOMIC ANALYSIS OF DESALINATION

Typically, the main economic parameters used to assess a desalination project are capital costs and operation and maintenance (O&M) cost.

These two components put together determine the total cost of freshwater production. This measure of water cost can be expressed as the ratio of annual capital and O&M costs (US$/year) to the target annual freshwater production rate (m^3/year). Then, the cost of water can be presented in monetary unit per volume of produced freshwater (US$/$m^3$).

The desalination technologies capital expenditure (CAPEX) and operational expenditure (OPEX) depends on a number of parameters. Some technologies require higher CAPEX due to land, engineering, unit purchase, transportation and installation etc. and others are leading in terms of high OPEX such as energy, maintenance, spares and labor. In the graphic below, the main drivers of water cost are reported.

Figure 2.6: Breakdown of desalination costs



Source: Shokri, Fard, 2022.

The capital cost is associated with all expenses for implementation of the desalination project, from the initial time of conceptual development, through to design, construction, financing, commissioning, and testing. Capital costs can be split in two categories:

- **Direct capital cost** (or constructions costs): these costs include direct expenses required to construct a plant, the purchase and installation cost of all facility equipment, and connection costs of plant piping for delivering produced freshwater to final consumers. Direct capital cost of a seawater desalination facility represents about 50% - 85% of total capital cost;
- Indirect capital cost: it accounts for the remaining 15%–50% of the total capital cost and is composed by costs incurred during the design and building of the project, such as administrative, contractor, and engineering costs.

Operation costs take into consideration expenses for running the desalination plant while maintenance cost refer to maintenance of building, equipment, and grounds. These costs can be divided into fixed and variable:

- **Fixed O&M costs**: they are independent from the scale of the desalination plant. They include amortisation, labor cost, maintenance of equipment, performance and environmental monitoring, administrative costs, and insurance. It is worth noting that some labor costs are related to plant size and should therefore be treated as variable expenses. Fixed costs represent about 15%–50% of total annual O&M cost.
- **Variable O&M costs**: they are a function of produced freshwater volume and include electricity and other energy costs, and expenses for replacement of filters and membranes, chemicals, and waste disposal. They account for the remaining 50%–85% of total annual O&M cost.

Levelized cost of water

The Levelized Cost Of Water (LCOW) or unit production cost of water in a region is usually expressed in dollars per cubic meter freshwater production (US$/$m^3$). It can be written in terms of capital and operating costs of desalination and water storage, electricity costs, and costs of water transportation to users. Rosen and Farsi (2022) provide a general equation to compute the LCOW:

$$LCOW = LCOW_D + LCOT_D$$

This equation combines the levelized cost of water produced from a desalination plant and the levelized cost of water transportation from the desalination plant to the users. More specifically, the levelized cost of water produced from a desalination plant is expressed as:

$LCOW_D = [((CC_D * CRF_D) + (CC_{ws} * CRF_{ws})) + (OC_{fix,D} + OC_{fix,ws})]/V_{fw}$

$+ (OC_{var,D} *SEC_D)$,

where:

- V_{fw} is the total volume of freshwater produced in m^3. The plant capacity is at the denominator, so it reflects the unit cost of capital investment in US$/$m^3$;
- CC_D and CC_{ws} are the capital costs of desalination and water storage units (US$);
- The terms CRF_D and CRF_{ws} are the capital recovery factors of the desalination plant and the water storage. The capital recovery factor is equal to the annualized factor in an economic analysis that describes the ratio of uniform payment made annually to the present value of the sum of the annuity over the given length of time (loan period);
- $OC_{fix,D}$ and $OC_{fix,ws}$ are the fixed operational cost of desalination plant and water storage (US$);
- The term $OC_{var,D}$ is the variable operational cost of the desalination plant. The product of $OC_{var,D}$ and SEC_D (specific energy consumption) represents the energy cost of the desalination plant in US$/$m^3$.

Similarly, the levelized cost of water transportation from a desalination plant to final user is expressed as:

$LCOT_D = [((CC_p * CRF_p) + (CC_{pipe} * CRF_{pipe})) + (OC_{fix,p} + OC_{fix,pipe})]/V_{fw}$

$+ (OC_{var,pp} *SEC_{,pp})$

This equation considers the same parameters as the previous one, but in this case capital and operational costs of pumps and pipes to transport water are considered.

Simplified cost of water

In scientific literature, the “annualised life cycle cost method” is the most widely used approach to compute the internal costs of desalination projects. This method is based on using an amortization factor α to annualise the initial capital costs of the desalination plant. The result obtained from this approach is known as the Simplified Cost of Water (SCOW); Papertrou et. al (2017) compute it as follows:

$$\text{SCOW} = \frac{(IC * \alpha) + O\&M}{Vfw},$$

where $\alpha = \frac{i\,(1+i)^n}{(1+i)^n - 1}$

The SCOW and LCOW approaches give practically the same results in most cases because in practice calculations do not go into much detail due to the lack of actual data. Two simplifications are used: the first assumes that every year (from 1 to n) the same amount of water V_{fw} is produced; the second assumes stable operation over the system's technical life, hence the desalination plant has exactly the same running cost (O&M).

As data confirmed, seawater desalination is costlier than other feed water like brackish water because it requires higher energy levels for salt rejection due to its relatively high salt concentration. Eke et.al (2020) report the average cost of seawater desalination, from the cost values documented by some plants. Data are taken from Global Water Intelligence. The analysis contributes to giving an order of magnitude of desalination costs, as well as enabling to some extent the comparison among different technologies and plant size. The major limitation is given by the fact that, despite Global Water Intelligence being one of the world's leading providers of water – sector information, water price data for only 107 plants is available.

Average prices for seawater desalination have been constantly fluctuating, with the peak and lowest average recorded respectively in 2012 (1.87 $/m^3$) and 2004 (0.35 $/m^3$). These prices largely depend on the salinity range of the seawater fed to most of the existing plants at that time. As a comparison, the average cost of desalinated water production from brackish water decreased from 1.53 to 0.4 $/m^3$ within the period 2002 till 2007. After then, the average cost continued to bounce back and forth until it reached 0.35 $/m^3$ in 2018.

From 1990 to 2020, the lower global water prices in seawater desalination are reported for RO plants, compared to MSF and MED plants; reverse osmosis global minimum prices in each plant scale (S-, M-, L-, and XL – scale RO) are all lower than the global minimum prices for XL – scale MSF and MED desalination. From the data analysis, the global minimum prices for S-, M-, L-, and XL – scale RO desalination are 0.14, 0.25, 0.298 and 0.36 respectively, whereas the global minimum prices for XL – scale MSF and MED desalination are 0.57 and 0.6 $/m^3$. For MSF and MED technology, only data from XL – scale plants are available.

It is interesting to observe that RO plants registered the maximum water prices recorded as well, suggesting that RO water desalination has a wider price range compared to MSF and MED. For MSF and MED technologies, the global maximum water prices reported at the XL scale are

1.13 and 1.3 \$/m^3, respectively. These values are lower than the global maximum values reported for XL-, L-, and M-scale RO desalination as 2.46, 1.9, and 1.95 \$/m^3.

Data on the global minimum and maximum water prices also shows that MSF is cheaper than MED at the XL level. This difference may be due to technological advancements that have resulted in the reduction of scale, corrosion, and cost of energy (required to achieve higher top brine temperature in MSF) in certain parts of the world over the years. If other technologies are included in the analysis, a particularly low water price of 0.26 \$/m^3 has also been reported for XL – scale ED desalination employed at the 200,000 m^3 /d Abrera brackish water ED plant in Spain.

Across all plants, the global maximum water desalination price of 2.46 \$/m^3 was reported for an XL – scale SWRO technology employed in Australia, whereas the global minimum water desalination price of 0.14 \$/m^3 was reported for a S - scale RO technology located in Romania.

In addition, there are some outliers in the data. This is because, apart from the technology used, the cost of water desalination depends on other factors such as the cost of infrastructure and capital needs, plant location, quality of feed and product water, source and price of energy and regulatory requirements, among others. For example, land acquisition costs are difficult to determine but they have an impact on the total capital costs. If not available, they are conventionally quantified in 2% of total construction costs.

The effect of plant size on water prices is unclear: even though it seems intuitive that a larger plant allows a more convenient distribution of fixed costs, literature doesn't support this idea. The cost varies with the size of desalination plants. GWI data interestingly show that, against the traditional norms of economies of scale, it is costlier to produce freshwater from large-scale plants than from small-scale plants. The average specific costs of producing freshwater (SCW) in small and medium-scale seawater desalination plants are computed as US\$0.55 and US\$0.51, respectively. For large and extra-large (XL) seawater desalination plants, the average costs of freshwater production are computed as US \$1.0 and US\$0.99, respectively. This trend may be derived by the capital-intensive nature of desalination with capital costs being the main determinant to the total cost.

3 – OSMOSUN CASE STUDY

3.1 – Reverse Osmosis technology: pro and cons

Reverse osmosis is the most common desalination technology nowadays, but it is also used, at low pressure, for the purification of fresh water. It is a membrane technology, hence it relies on a system of membranes retaining dissolved solids and thus producing a stream of pure water, called permeate, and a stream of rejected ions, the so called "brine". This method allows a reduction in energy consumption unlike thermal methods because the energy does not enter directly into the desalination process. RO technology, unlike thermal technologies, doesn't require thermal energy for evaporation. Thanks to this lower energy consumption and to compact systems easier to set up, RO replaced thermal technologies and represents 95% on new installations.

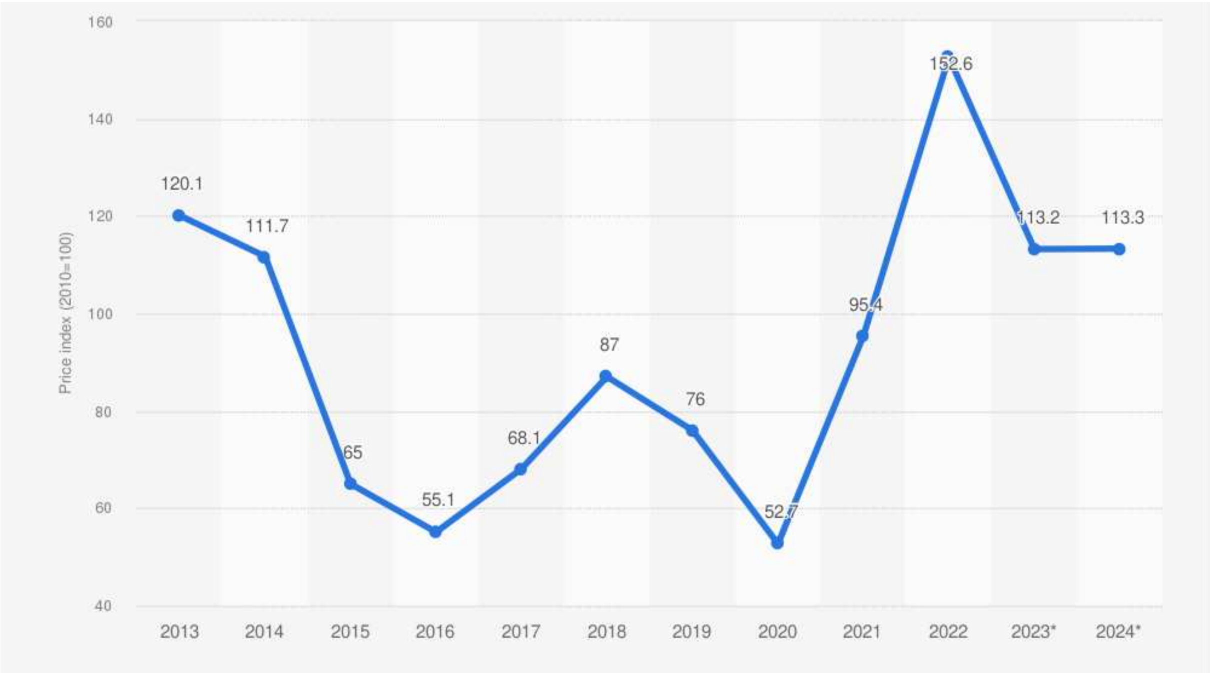
3 main arguments explain the conversion and use of RO:

- **It is more efficient due to its scalability and flexibility**: RO technology is modular, which allows rapid addition and assembly of new units, unlike thermal technologies which depends on energy and available space;
- **It is also less expensive**: On average, reverse osmosis costs €0.15/m^3 of investment capital compared to more than €0.22/ m^3 for thermal technologies. Operating costs are reduced as well(on average 0.28 €/m^3 for RO technology compared to 0.46 €/m^3 – 0.59 €/m^3 for thermal technologies). This difference in operating costs is mainly due to the presence of energy recovery devices on the RO desalination units;
- **RO desalination is more eco-responsible and sustainable**: As shown in Chapter 2, specific energy consumption is lower in RO. Reverse osmosis consumes on average 1.5 to 4 kWh/m^3 compared to between 6 to 13 kWh/m^3 for thermal technologies. The rejected brine is approximately 1.5°C warmer than the temperature of sea water compared to 5°C to 15°C for thermal technologies**;**
- Another attractive feature of RO is the possibility to handle highly concentrated feed water like brine; RO accounts for a capacity of 129,336 m^3/d from brine (re)desalination, which is far higher than the combined contribution of all other desalination technologies to brine (re)desalination (Eke et.al, 2020).

Apart from this advantages, adoption of reverse osmosis technologies has also been favoured by stricter global environmental regulations, which have been trying to promote an efficient use of energy to mitigate its impact on the environment.

However, in 2022 operating costs for all desalination plants worldwide amounted to €10.1b and 40% of these costs were linked to energy. This represents an average global consumption of 80 TWh/year: to give an order of magnitude, it is higher than Chile's electricity consumption of 75 TWh/year. Energy costs have a huge incidence on total desalination costs. The graphic below shows the variations in energy prices in the last 10 years.

Figure 3.1: Price index of energy raw materials, 2013 – 2024



Source: Statista, 2023.

On a base of 100 in 2010, the increase in the price of energy raw materials amounted to 100 points between 2020 and 2022, in contrast with a significant decline in the previous years. This period is characterized by two significant events: COVID-19 pandemic and the war in Ukraine. The use of renewable energies is essential to enable companies to reduce their greenhouse gas emissions and their carbon footprints and to comply with country regulations and global agreements such as the Paris agreements whose ambition implies, according to IRENA (International Renewable Energy Agency), multiplying by six the speed of development of renewable energies.

Cons

While RO brings economic advantages relatively to distillation processes, it is still limited by the challenge of membrane fouling. Compared to thermal technologies, reverse osmosis is a more delicate process, mostly because the membranes used are sensitive to variations in flow and pressure.

The most common fouling mechanisms are colloidal and particulate, organic, inorganic and biofouling mechanisms. To address this matter, pretreatment steps are required both to maximize the efficiency of RO and to extend the life span of RO membranes (Eke et. al, 2020). To this end, multiple pretreatment steps may be required, depending on the quality of feed water.

The problem of membrane foulings also explains why Middle – Eastern countries have continued for long time to rely on thermal distillation desalination technologies for the production of about half of their total desalination production capacity. This problem is exacerbated in the area by the extremely high salinity levels of the Red Sea and the Gulf Sea. Cost of membrane replacement will significantly affect the operating cost of any RO plant operating in this region (especially for freshwater recovery from brine); on the positive note. the recent and newly contracted plants in this region are mostly RO plants due to advances in RO membrane cleaning.

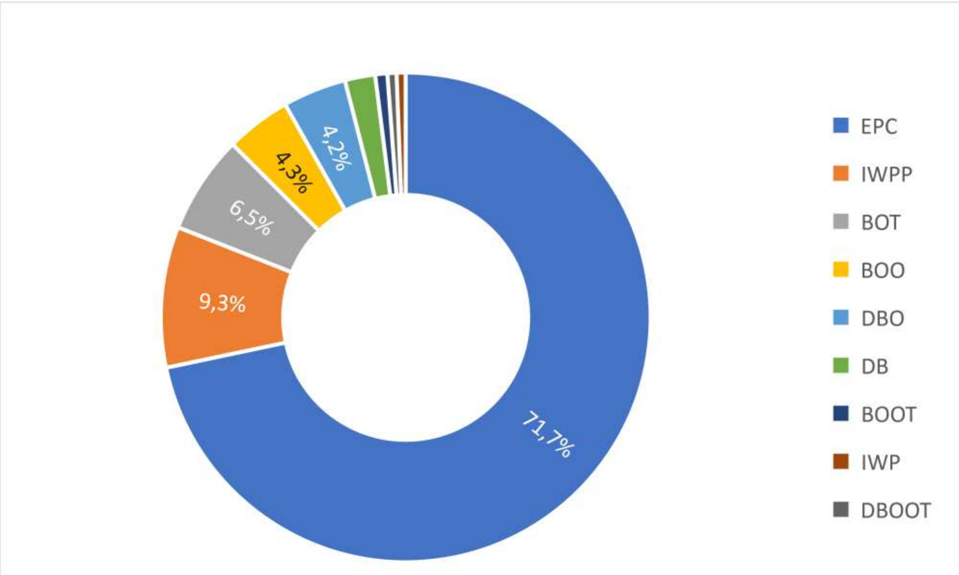
3.2 – PROCUREMENT MODELS

From the economic analysis in Chapter 2, it emerges that large-scale desalination projects are capital-intensive to the point that cost of producing freshwater is higher in large plants than in smaller ones. As a consequence, it comes with no surprise that key stakeholders in large-scale desalination projects are mostly public institutions and large corporations.

Typically, the public agencies provide water from the source while the private firms are responsible for engineering, construction and development services. The main advantages of these partnerships are reduction in financing costs and increased efficiency of the overall process.

In some cases, the public agencies run the plants or allow the private firms to own and operate the plants, based on long-term contractual agreements. Long-term contracts are preferred because they allow to recover capital costs over the duration of the partnership. Several procurement models for the delivery of desalination plants have been studied and implemented.

Figure 3.2: Procurement Models by installed capacity



Source: Eke et.al, 2020.

The Engineering-Procurement-Construction (EPC) model contributes to about 71.7% of global installed desalination capacity, with the EMEA region being the area where it is mostly adopted. In the EPC model, the public agency maintains ownership of the desalination plant and the private firm acts like a service provider. The private company bears all operational risks.

The Independent Water and Power Producer (IWPP) model is the second most common model, as 9.3% of global desalination capacity is contracted under this model; all IWPPs are stipulated in the EMEA region. The complexity of this model requires coordination and cooperation between large and well-established institutions.

IWPPs sell their capacity or outputs to the public agencies. A single long-term contract (i.e. 30 years) is established between the public body and the private firm (usually a large organization or an assemblage of several private sector organizations) with the goal of ensuring constant supply of water and power to the public agency. Responsibility for funding, engineering design, organization, construction and management is given to the private firm. A similar model is put in place when the private firm produces water only: in this case, we talk about Independent Water Producer (IWP) model. IWP model accounts for less than 1% of global desalination capacity.

The Build-Own-Transfer (BOT) model is the third most common model, accounting for 6.5% of global desalination capacity. The private firm is enabled to build and own the plant by the public entity through a concession. If the private firm is also allowed to operate the plant, then the model becomes Build-Own-Operate-Transfer (BOOT) where the private firm collects revenues, operates and maintains the infrastructure. At the end of the concession period, everything is transferred back to the public agency. BOOT contributes less than 1% to global desalination capacity.

Other procurement models like Build-Own-Operate (BOO), Design-Build-Operate (DBO), Design-Build (DB), Build-Own-Operate-Transfer (BOOT), Independent Water Producer (IWP) and Design-Build-Own-Operate-Transfer (DBOOT) models are not typically used for desalination projects, accounting for less than 10% to global desalination capacity. Although these procurement models may be suitable for certain projects, they suffer from lack of appropriate legal framework, risk of infrastructure damage or destruction in case of political unrest and have little history of private partnership with the public government of a country.

The following section will be dedicated to the presentation of a case study which gives an insight of what takes to a company to be competitive in the ever-evolving desalination market.

3.3 – COMPANY PRESENTATION

Created in 2014, OSMOSUN is a French company based in Gellainville which produces desalination units with the mission to provide "water everywhere for everyone" and the promise to accelerate the green energy transition in the water market. The company relies on a major patented innovation thanks to which it has enabled communities, utilities and private organizations around the world to produce fresh water in almost all geographic locations at an affordable cost, while reducing the carbon footprint linked to water production through the use renewable energies. This value proposition has been built over the last ten years in two separate phases: first, the completion of several key R&D stages between 2014 and 2018, followed by the acceleration of commercialization from 2019. In July 2023, an important step was made by the company with the Initial Public Offering on the Euronext Growth in Paris.

The commercialization in recent years is reflected by the numbers: OSMOSUN has experienced a 4-fold increase in units installed between 2020 and 2022. When the Company presented the registration document for going public in June 2023, it reported 59 units sold in 27 countries, 51 of which operational and 8 being installed. The units sold by the company account for a total production of 2,500,000 m^3 of drinking water, which means that about 50,000 people gained access to drinking water thanks to the company's products.

The company has developed a low carbon reverse osmosis desalination solution for seawater and brackish water running on solar energy. The technology used by OSMOSUN is considered 4 times less energy intensive than thermal solutions: 1.5 to 4 kWh/m^3 for reverse osmosis, while thermal energy requires 6 to 13 kWh/m^3.
Furthermore, this solution allows to avoid 4,000 tonnes of CO_2, according to data provide by the company. Regarding brine discharge, OSMOSUN obtains only 5% difference in salinity compared to seawater input and has set up a system of lagoons for brackish water.

The interest in OSMOSUN solutions is growing across all geographic areas and market segments, in particular where development is speeding up in a context of strong tension on water resources. The market segments already served are urban and rural communities, industry (i.e. mining and hydrogen), hotels, Non-Governmental Organizations (NGOs), agriculture, emergency and army.

OSMOSUN innovation

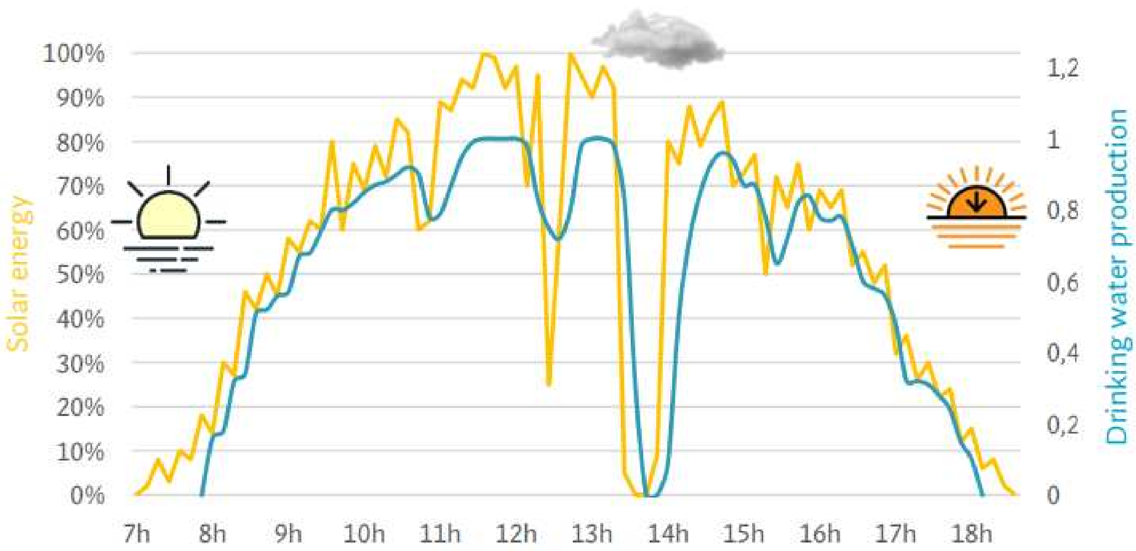
OSMOSUN's product innovation relies on two main technologies: desalination of seawater and brackish water through reverse osmosis and photovoltaic solar panels.

The technology of desalination of seawater or brackish water by reverse osmosis has been known for more than thirty years and today it is recognized as a mature technology. The technology of photovoltaic solar panels makes it possible to produce electrical energy from solar irradiance and its maturity is expressed by raising efficiency and falling prices.

The reverse osmosis process is classically developed for continuous freshwater production with fixed equipment adjustment parameters and constant consumption of energy. On the contrary, solar energy production is subject to variations depending on the weather and the day/night cycle. Due to their specific features, these two technologies are not a priori compatible: an energy-storage battery is required to smooth and make permanent the energy generated.

To address this limitation, the company has introduced a novelty to the market: OSMOSUN has developed a patented innovation allowing the units to manage the random variation of the available energy during the reverse osmosis process. This innovation is claimed as the only battery-free reverse osmosis technology on the market that can operate "as the sun goes" with variable energy without stopping production and damaging the membranes. a variable reverse osmosis process capable of instantly adapting to the amount of energy available.

Figure 3.3: OSMOSUN patented innovation



Source: Company

In this way, it is possible to compensate for irregularities and fluctuations in solar energy thanks to a fully automated system with a hydraulic accumulator which absorbs fluctuations, a frequency variator powering the pumps according to the available solar energy and an intelligent energy management algorithm that manages solar interaction, all without the need for battery storage. Operational and economic control of operating costs is guaranteed by a self-consumption plan for the energy produced by the desalination unit. While this innovation makes it possible to respond to supply shortages in many regions of the world, it also offers highly competitive fresh water (€0.87/m^3 on average), defying most competing offers (between €1.61 and €2.55/m^3), contributing to the widespread democratisation of low-carbon solar desalination in all areas in need.

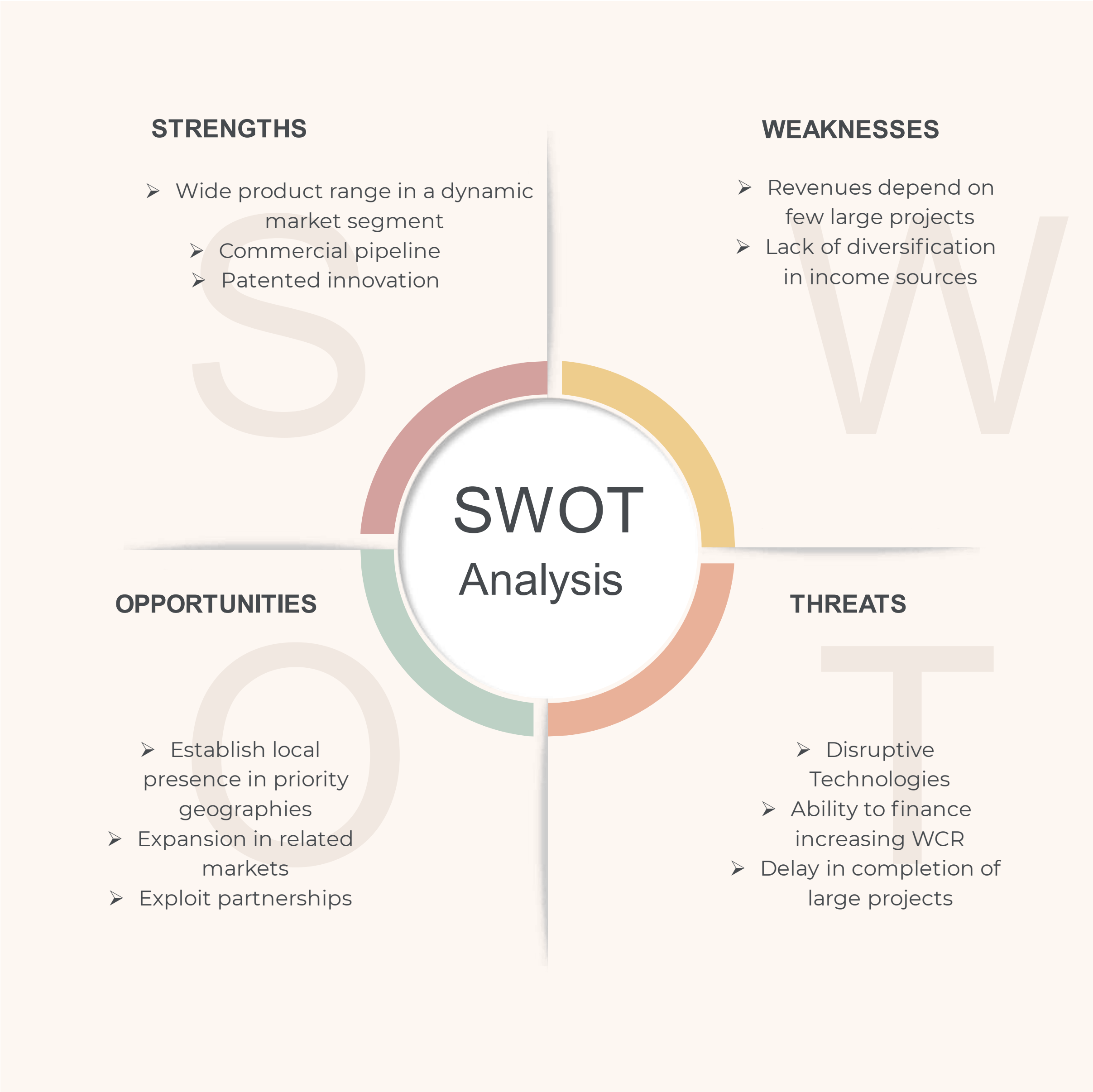
This patented innovation brings several advantages:

- **Autonomy**: thanks to the battery-free solar energy innovation, units don’t need to be connected to an electricity network without generators or fossil fuels;
- **Economy**: cost of solar energy production ranges between 0.02 and 0.04 €/KWh hour, compared to conventional energies which can reach 0.4 €/KWh in certain countries;
- **Ecology**: ecology is granted by the absence of battery that need to be transported, replaced, recycled or more often thrown away. The day's energy is stored in the form of fresh water in a reservoir. This water will thus be available 24 hours a day;
- **Maintenance**: the machines are simple, robust and designed to be maintained and repaired locally. For example, energy recovery pumps have a high Mean Time Between Failures (MBTF) and maintenance operations are required every 8,000 hours. OSMOSUN offers optional remote monitoring which allows the machine parameters to be monitored remotely, to alert if necessary and to support the worker if necessary.

3.4 – SWOT ANALYSIS

In this section, the SWOT analysis provides an internal point of view on OSMOSUN competitive advantages and margins for improvement.

Figure 3.4: OSMOSUN SWOT ANALYSIS



Source: Personal Elaboration

Strengths

Wide product range in a dynamic market segment

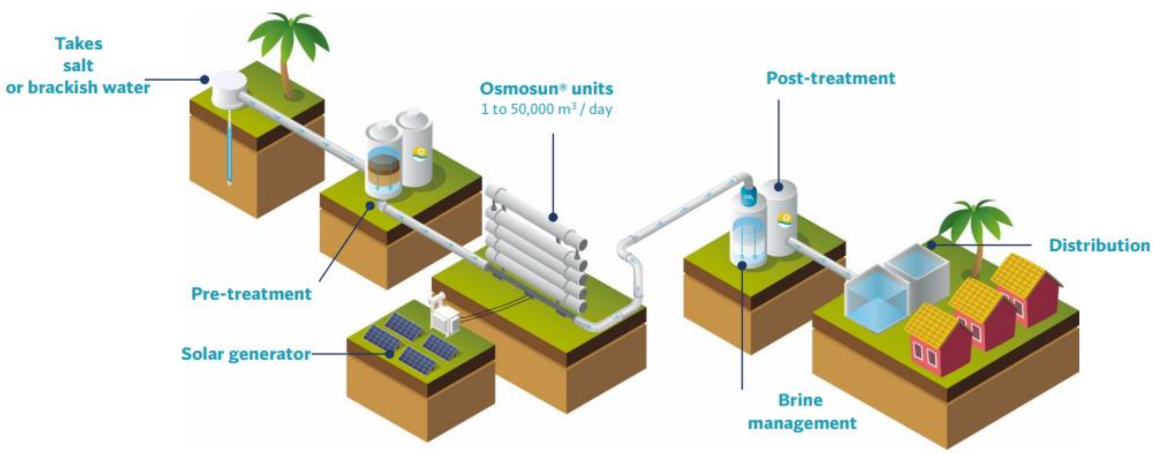
The company offers its products in two lines: standard solutions and tailor- made solutions. Standard solutions refer to units below 300 m^3/day: they are characterized by short completion time (3 to 4 weeks) for production, delivery and installation. This requires the company to keep a safety stock of the main components involved. Besides, total cost is limited by the absence of design and study cost.

To optimize the cost of water production at local capacities, OSMOSUN units can operate under two types of energy supplies:

- **Off-grid**: 100% autonomous, they operate from sunrise to sunset thanks to photovoltaic panels, providing drinking water at a competitive price even in remote locations;
- **Hybrid**: the desalination units are powered by both the electricity network and photovoltaic panels to produce water 24/7, with intelligent energy management coordinated between the electricity network and the solar field of photovoltaic panels.

Solutions above 300-500 m^3/day are tailor-made solutions because they either include specific features requested by the customer or adapt the design to the context where the solution will be installed. The tailor-made projects are mainly used in areas where electrical infrastructures are present and hybrid solar/electricity grid solutions for the power supply of the treatment units are implemented. The completion of a tailor-made project lasts from 4 to 18 months.

Figure 3.5: Solar desalination plant by OSMOSUN



Source: Company

The Company mainly supports local authorities, industrial and private players throughout the world in the implementation of suitable desalination solutions.

An important point to stress is that OSMOSUN addresses the most dynamic market segment: small units (from 1 to 50,000 m^3/day) represent almost the totality of new installations and provide fresh water with decentralized units that can operate in isolated areas; besides, these units better approach current issues such as cost reduction and management of negative externalities. According to GWI, units <50,000m^3/d should experience strong growth with a CAGR of +12.3% for the period 2022 – 2027, far higher than +4.5% for the rest of the market. In 2027, this market segment is expected to reach €3.4 billion based on CAPEX deployed.

The company aims at offering products which differentiate themselves with a modular approach that natively integrate and favour the use of renewable energies. Modules are designed to fulfil their function but above all must prove to be hydraulically, mechanically and electrically interconnectable to the other modules. This interconnection must be robust and easy to implement. From an economic point of view, the modular approach will reduce cost prices by at least 5% in order to preserve margins and improve OSMOSUN's competitiveness in the market.

Commercial pipeline

Growth ambitions of the company are justified by a commercial “pipe” which amounts to more than €160 million on the date of approval of the Registration Document. This commercial “pipe” is made up of firm orders for €5 million, contracts currently under advanced negotiation for €38 million and other projects currently being qualified or identified for €121 million.

In addition, the Company integrates, in support of its development policy, the monitoring of calls for projects and calls for tenders from international financial institutions, NGOs and UN institutions. The commercial expertise of the company in monitoring and successfully applying for these projects represents a key factor to support its expansion in the key geographical areas.

Weaknesses

Diversifying sources of income

At present moment, the company's revenues mainly depend on the sale of turnkey projects that include design, tailor-made equipment, installation and commissioning. The average project size is quite small, but revenues per project are set to increase: €450k/project in firm orders compared to €850k/project in advanced negotiations.

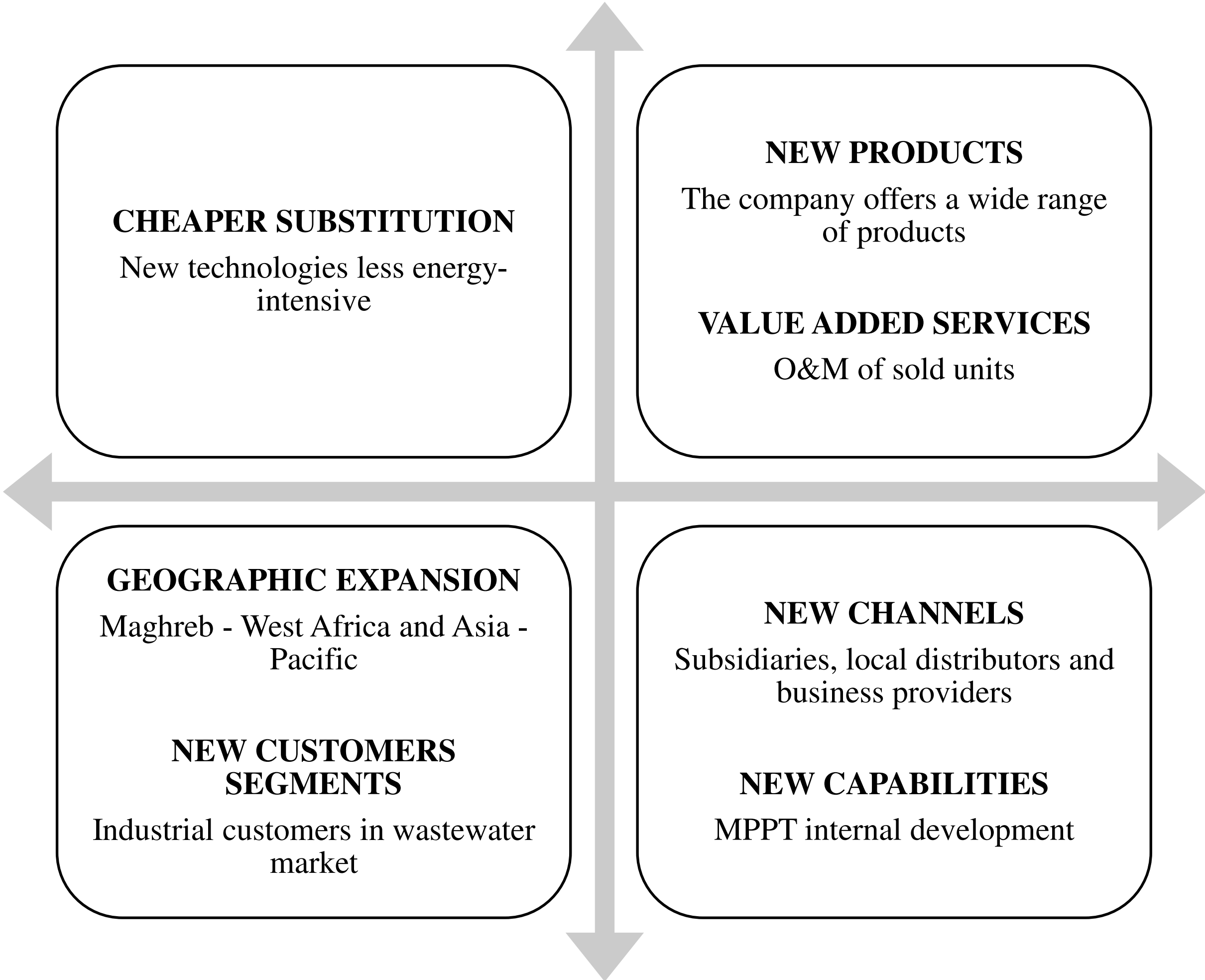
The company aims at expanding its sources of income, leveraging on three main additional sources:

- **Sale of spare parts and chemical products**: according to GWI estimates, OPEX linked to the replacement of wearing parts represents nearly 15% of desalination OPEX. Thus, according to management estimates, replacement costs for spare parts represent, on average, 35% of initial CAPEX over the first 10 years of operation. Therefore, establishing an after-sale relationship with the customer for the sale of spare parts necessary for maintenance (either long-term or ad hoc) has the potential to become a recurring source of income;
- **Operational assistance with support for O&M**: This expansion of OSMOSUN's position on the value chain requires a strong local anchor, but also ability to potentially manage a large number of projects implemented in the same geographical area;
- **Current position for other water treatments**: technologies implemented in the context of desalination are numerous and some are applicable for the treatment of surface, underground or industrial water.

Opportunities

To achieve development objectives, the Company has clearly stated its intention to pursue an organic growth approach rather than an external growth path. External growth opportunities will only be considered depending on eventual market opportunities but do not represent the primary choice for the company to expand its business. The figure below illustrates areas related to the company existing business. Expanding the business in adjacent areas brings more opportunities to create value, whereas entering in completely different markets where the company has no knowledge might result in a waste of time and resources.

Figure 3.6: Map of Adjacencies



Source: Personal Elaboration

Establish a local presence in priority geographies

The three macro areas identified by the company to build the development strategy are Maghreb/West Africa, Asia-Pacific and Latin America. Depending on the countries in the geographical areas where the activity is deployed, OSMOSUN has chosen an omnichannel commercial strategy which revolves around three sales channels:

- **Local channels**: offices or subsidiaries established in the priority areas. These are direct contacts made by the sales team composed by several "business developers", each in charge of a geographical area;
- **Distribution partners**: suitable for countries with little market depth, they allow to seize opportunities without development efforts;
- **Network of business providers**: paid on commission, they are legal entities which submit commercial opportunities to the company, which is responsible for transforming them into a business.

Proximity to the local level is considered key to provide solutions suitable to the needs of the local players and to the characteristics of the local markets. Knowledge of specific local conditions and access to key decision makers is highly valued by investors and financiers (OECD, 2021).

Of course, the small dimension of the company doesn't allow to develop all the key areas at the same time: the first two priority areas where this strategy is deployed from 2023 are Maghreb – West Africa and Southeast Asia-Pacific. In particular, the African content is a market which offers strong opportunities: the Sub-Saharan Africa desalination market accounted for €51 million in 2022, but is expected to reach €200 million by 2027, with a CAGR of 37%, the highest among all regions. Despite being one of the most water-scarce areas in the world, it is also an underserved market, which leaves a lot of people without basic drinking and sanitation services.

In October 2023, the company announced the creation of a joint venture with the Moroccan industrial group PCS. Morocco is one of the most mature desalination markets in Africa: the government aims to increase its reliance on desalination to provide drinking water to the population, reaching 50% by 2030. This new entity will offer tailor-made solutions, while PCS will take responsibility for post-installation support. This local presence will enable OSMOSUN to diversify its source of revenue; moreover, rather than only selling desalination units, the company could operate its units following a "Build, Own, Operate" contract model.

Wastewater and Reuse market as a related sector

In regions of the world facing significant water stress, wastewater reuse can be a sustainable and effective solution to meet water demand. Asia Pacific, North America and the MENA region are the global leaders in the wastewater reuse market with 37%, 27% and 19% of global capacities respectively in 2022. The wastewater reuse market is expected to continue to grow in the future. By 2025, the world's cumulative installed capacity will be around 220 million m^3/day (compared to 190 million m^3/day in 2022), representing annual growth of 5% (GWI, 2020).

As discussed in Chapter 2, the main application of the reuse market is the industrial sector (pharma, agri-food, microelectronics), followed by irrigation for agriculture and green spaces. The reuse of wastewater for direct use in drinking water is very limited to date, with around 2.5 million m^3/ day of cumulative installed capacity globally in 2020. Of the 380 billion m^3 of wastewater produced worldwide per year, only 20% is treated before being released into the environment, and only nearly 0.3% is treated to be reused. Growth in the reuse market is expected to continue to increase, driven by changing regulations and increasing water demand.

One of the main reasons that explain why such little wastewater is treated for human consumption resides in a psychological barrier among the population, known as “yuck factor”: consumers are reluctant at the idea of utilizing recycled water and suspect that it could be unsafe. A paradigm shift is underway and must accelerate to consider wastewater as a potential resource rather than as a discharge to be depolluted. For example, the city of Singapore is a pioneer in this field, covering 40% of its drinking water needs by reusing wastewater. Before the launch of the project, a significant effort was made on communication, public education and information actions.

In order to make wastewater drinkable, additional treatments are necessary; as in desalination, water can be treated by reverse osmosis. The “low carbon” RO technology developed by the group can thus be deployed for the production of directly potable water – or simply purified water, suitable for industrial or agricultural use. Therefore, OSMOSUN could potentially exploit its dual expertise in water and energy to penetrate this market.

Reuse market is very complementary to that of desalination and represent an ideal target market for the company, even though gross margin levels are expected to be inferior to those observed in desalination due to competition and lower value attributed to the innovation brought by OSMOSUN. On the positive note, cost synergies related to purchases of raw material and components and optimization of production equipment could limit dilution in terms of EBITDA.

Exploit partnerships

As discussed in Chapter 1, partnerships represent a concrete way to speed up the pace in order to reach SDG’s target. OSMOSUN has a direct positive impact on SDG 6 and 7. OSMOSUN exploits partnerships in a variety of ways:

- **Civil engineers**: international or local companies (i.e. Eiffage, Vinci, Colas) with expertise in structural work and infrastructure know-how into which OSMOSUN can integrate its water treatment process equipment. In the majority of cases, these partnerships are implemented within the framework of a very specific project opportunity;
- **Solar developers**: considering the potential application of solar technologies to desalination, they become valuable partners;

- **Distribution partners and network of business providers**: they contribute in diversifying income sources.

The increase in the average size of projects brings an increased complexity of the associated civil engineering. Solar desalination projects between 500m^3/d and 5,000m^3/d may involve the construction of water intake, transport and/or storage infrastructure in fairly specific coastal contexts. OSMOSUN has therefore established links with major players in civil engineering. The most recent example is the Brava project, budgeted at €5.2M including €1.5M for OSMOSUN and just over €3M for civil engineering. On this project, nearly €0.5M was also dedicated to the photovoltaic installation which was also to serve as a reinforcement node for the island's conventional electricity network. This type of partnership provides a two-fold advantage: it allows the company to position itself on large-scale projects, while building a secondary network of business providers.

Similar relationships could be established with IPPs in the solar sector. OSMOSUN has already joined forces with Akuo Energy Indonesia to address arid island areas where the cost of energy is particularly high. This partnership could lead to the development of projects in the form of service contracts with associated water sales in the eastern islands of Indonesia; a business model complementary to that which the group has historically developed and which could introduce a little recurrence.

For example, a project addressing a critic water situation in the Komodo National Park in Indonesia regarding more than 400 families has been carried out. The island has no exploitable fresh water and can only rely on brackish water. A solar generator was installed (providing 5 kWp) to supply energy to the OSMOSUN unit, allowing “green” water to be produced; the final price resulted to be lower than the local alternative of buying water on land (Mazzega, Cassignol, 2022).

Threats

Disruptive Technologies

Reverse Osmosis is currently the most economical process for a wide range of salinity feedwater. Of all desalination technologies which have been deployed so far, reverse osmosis is the most used and has been used for desalination of all types of feed water, indicating that the technology is mature and well developed. For low salinity feeds, mature processes such as electrodialysis (ED) and electrodialysis reversal desalination (EDR) are considered. Other emerging processes, such as forward osmosis (FO), adsorption desalination (AD), and membrane distillation (MD) are under development and may have a great potential in the future; for the moment, these solutions are rarely adopted (Bundschuh et.al, 2021).

Delay of large projects

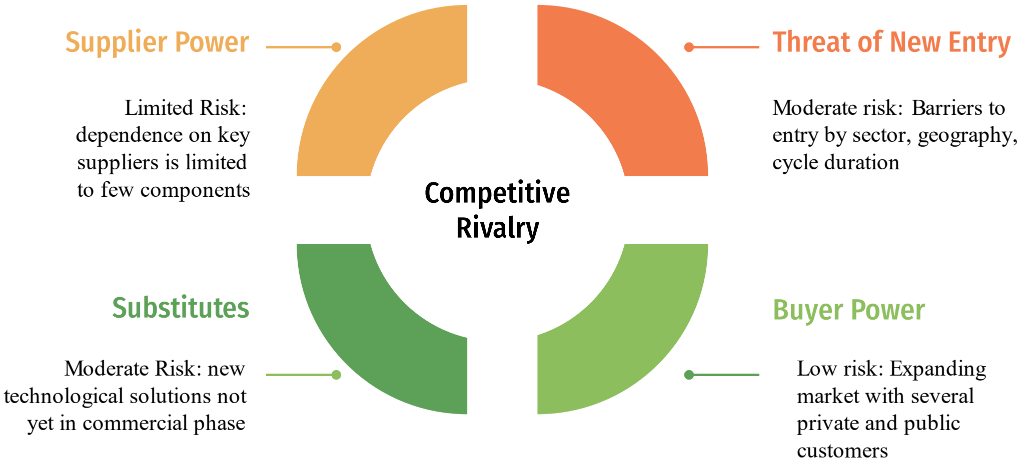
The company has an evolving portfolio and seeks diversification in the size and number of projects and clients for which it operates: one of the main risks that the company faces is the dependence on the most significant projects. The Company is currently working on two significant projects, and no longer on just one for the same financial year; in the long term, the goal is to work on 5 or 6 projects to better distribute the associated risks.

Furthermore, to reduce risk of non-completion of projects, the company carefully selects partners and clients, which are usually large international organizations. The company doesn’t participate in public projects unless they are financed by a development bank or a UN agency. OSMOSUN has set up a business model based on progressive recognition of revenue for each project, enabling the company to finance a large part of its working capital. Revenues are recognized in three phases:

- 30% of the total amount of the invoice upon signature of the contract;
- 40% at the time of shipment of the elements composing the solution designed for the client;
- 30% at the time of installation.

3.5 – PORTER 5 FORCES

Figure 3.7: Porter's 5 forces



Competition in the industry

The global growth of the desalination market pushes many players to compete in this industry. Data gathered by GWI Desaldata show that, between 2016 and 2022 nearly 2,400 desalination plant projects using reverse osmosis technology were won around the world. Over this period, 172 plant suppliers are listed, including OSMOSUN. First of all, what emerges is the fragmentation of the competition in the industry. Plant size is divided in S (< 1,000 m^3/day), M (1,000 – 10,000 m^3/day), L (10,000 – 50,000 m^3/day) and XL (> 50,000 m^3/day). The dynamism of small – medium market is backed up by data: 161 suppliers are listed in the small – medium market (S to L), compared to only 39 suppliers operating in the XL market. Only 11 players are operating exclusively in the XL market.

Indeed, the nature of XL projects justifies this numeric difference. Carrying out a XL project is out of reach for most companies due to several reason: around 70% of listed XL projects are executed in the public sector, which implies a complex and costly tender process for the bidder. In addition, a certain critical size and either a wide range of skills (from design to operation) or the establishment of partnerships is needed. Finally, these projects are also characterized by a particularly long development period (on average, XL projects between 2016 and 2022 took 4 years between obtaining the call for tender and the start of operation in the factory). All of these factors create a strong barrier to entry for projects over 50,000 m^3/day.

Usually, the suppliers of desalination units offer a range of single-piece equipment integrating all the processing stages and powered by a conventional energy source; this goes independently from the type of feed water. The main limitation of this well-established approach is the capacity for adaptation. Indeed, when the typology of water to be treated becomes very broad, a certain flexibility is required and it becomes essential to have a suitable offer.

The following qualitative (and non-exhaustive) map of the company's main competitors helps in understanding the company positioning, with respect to the type of energy utilized in the desalination process and to the service offered to the customers.

Figure 3.8: Map of OSMOSUN competitors

Source: Personal Elaboration

In the small-medium market, OSMOSUN distinguishes itself from competitors by focusing on turnkey solutions that can be customized to the customer's needs, allowing the company to achieve sectorial flexibility. This generates multiple advantages:

- Capacity to carry out projects from 1 to 50,000 m^3/day independently;
- Profitable relations with both equipment manufacturers and customers;
- Augmented visibility in the market.

Due to sector-specific constraints, OSMOSUN direct competitors in the small-medium market, identified by number of employees and use of renewable energies, tend to specialize in a single sector and to focus on an assembler positioning that requires fewer skills by providing standardized solutions to enter the market. This positioning is easier to access but does not make it possible to respond independently to more complex projects with a capacity greater than 10,000 m^3/day, as well as limiting the range of solutions offered.

Therefore, this positioning pushes OSMOSUN into a broader competitive environment where we find traditional desalination players, which provide turnkey solutions in different geographies. Broader sectorial and geographic positioning is possible thanks to the size of these players, who mostly have more than 100 employees. If we compare OSMOSUN to this competitors, the company's value proposition still remains strong:

- OSMOSUN is the only player providing both "turnkey" solutions coupled with renewable solar energy;
- Very few players apart from the very large ones (SUEZ, Culligan, Metito) and Temak are present in Africa, a region where OSMOSUN is already established and which has both the largest growth forecasts in the desalination market (37 % CAGR 2022-2026) and the largest photovoltaic energy potential in the world (GWI Desaldata).

These peculiar features make OSMOSUN unique and without direct equivalent in the market segment addressed.

New entrants

Among suppliers of S to L plants, a high degree of specialization emerges. Three major entry barriers are represented by cycle, geography and sector constraints.

First of all, a strong positive correlation between project size and deployment cycle duration is observed. XL projects typically follow cycles ranging from 18 months to 5 years between obtaining the call for tender and the start of factory operations. Undertaking projects with these features requires a wide range of skills, as well as the financial ability to face a long development process which lasts on average four years. On the contrary, small and medium capacity suppliers benefit from shorter cycles; since their dimension is typically small, they are able to execute a single project, but then the ability to remain in the market depends on their internal capacities to honour several projects in parallel.

OSMOSUN knows how to adapt to varied deployment cycles. Looking at the company history, two major contracts signed with Eremet and Chohan Group constituted, in 2021 and 2022, the 67.3% and 65.2% of turnover, respectively. Over the following years, the company aims at diluting its risk of dependence on key clients, distributing its activities over 5 to 6 major projects.

From a geographical point of view, of the 161 suppliers listed having completed S to L factories between 2016 and 2022, the vast majority (71%) are active in only one region of the world versus 29% active in two or more regions (GWI Desaldata, 2022). 73% of the listed actors have carried out less than five projects, so they are likely to be carried out in a single geography.

Another major barrier to entry linked to geography is the need to master the local context and to be present on-site to ensure the smooth running of the operations. These elements are even more relevant when the supplier is also responsible for the operation of the factory: this contract type requires a full-time local team. Such deployment of resources is often difficult to achieve for small companies which do not have sufficient size and human resources to meet these needs, thus creating a geographic entry barrier for small and medium capacity suppliers.

As far as sectorial specialization is concerned**,** 92% of 161 suppliers in small-medium market carried out projects either in the public or in the industrial sector. However, only 22% delivered projects in both sectors: one of the main obstacles to serve both sectors lies in the diversity of input quality and use required by each sector. This sectorial specialization in the market is also accentuated by the fact that almost half of desalination plant suppliers (46%) have only won one project listed over the 2016-2022 period.

Substitution

The intense activity in small-medium market suggests a high turnover in market players. Even though it is true that many companies enter the market, most of them do not establish a permanent presence in the market, as shown by data on numbers of projects completed (73% of S – L suppliers completed less than five projects). This strategy, which may result from opportunities given by peculiar characteristics of a single project, does not make it possible to maintain a long-term presence in desalination due to the difficulty of overcoming the constraints of cycle, sector and geography.

The main threat of substitution may come from new entrants bringing disruptive technologies, especially those related to solutions less damaging for the environment. The inability of the company to keep up with innovations in this field could represent a serious threat to its development.

As already discussed, the desalination sector is still looking for solutions to lower costs and reduce its environmental impact; one of the main areas of concern regards brine discharge, which to present days still represents one of main drawbacks of reverse osmosis technologies. Several alternative solutions are under study, like zero liquid discharge (ZLD). This process aims to maximize freshwater recovery and minimize waste by producing solid salts instead of liquid brine and has promising perspective for improving brine management after the desalination process (Panagopoulos et.al, 2019).

OSMOSUN is already trying to find new ways to cope with environmental challenges: a possible response is phyto desalination, which allows to manage concentrates instead of releasing them into the natural environment and can be applied to all brackish water desalination installations located inland without access to the coastline.

The technical objective is to offer customers a solution which makes it possible to limit the problem of concentrates, by cultivating plants which will be able to absorb/fix salts and reduce the liquid volume of discharges by evapotranspiration. From an economic standpoint, the concentrate can become a by-product capable of producing economically valuable biomass following its transformation. Removing this brake will make it possible to accelerate OSMOSUN's development in the BW (brackish water) reverse osmosis market segment.

Suppliers' power

Develop an MPPT

OSMOSUN sources several components from external suppliers and availability from different suppliers is considered in choosing which components to use. Even though the company operates with renowned suppliers with a reassuring performance record, this adds uncertainty to the delivery times of the company's products, as well as exposing the company to risks related to increase in production costs, mainly arising from energy prices and labour market.

In particular, OSMOSUN currently works with only one supplier of special frequency inverters with integrated Maximum Power Point Tracker (MPPT). The company plans, starting from 2023, to use an internally developed MPPT algorithm, estimating its need in around 150 installed units per year. This internal solution will help the company in mitigating the risk deriving from sourcing several components from external suppliers; economically speaking, OSMOSUN will significantly reduce the costs for this component.

Compared to a current average price charged by its supplier of €1,500 per unit excluding taxes, the average price thanks to the development of the MPPT algorithm inserted in a standard drive should be €500 per unit excluding taxes.

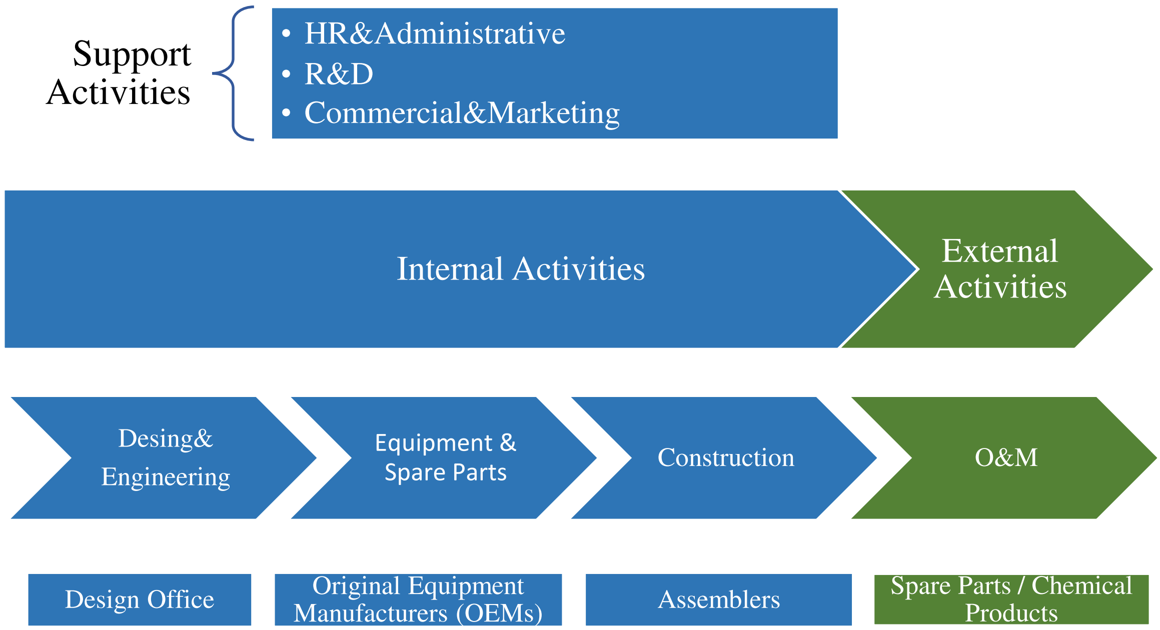
Customers' power

The Company mainly works with national and international organisations, which commission projects in order to provide essential drinking and sanitation services to the general population. When working with these entities, cooperation is an important pillar to ensure the smooth completion of the projects, which may be carried out in challenging situations. As for private sector clients, the preferred contracting model remains direct plant purchase where the client finances the project with its own funds. This model is particularly widespread for small projects (<10,00 m^3/day) due to lower complexity and smaller investment. Usually, private clients prefer to maintain control over infrastructures critical to their industrial process.

However, BOT and BOO models are developing at fastest pace in the industry: 81% of additional operational capacity in 2022 was contracted under these models. The main advantage is the possibility to transfer both technological and delivery risks from the end customer to the private actor and to rely on external private investors to finance CAPEX needs rather than being limited to the financing capacities of the end customer. This model is particularly popular for large projects, generally in the public sector, with significant financial and technical constraints.

3.6 – VALUE CHAIN ANALYSIS

Figure 3.9: Activities executed by OSMOSUN along the desalination value chain



Source: Personal Elaboration

OSMOSUN value proposition covers the design, construction, equipment sales and installation of OSMOSUN units, thus offering to its clients a "turnkey" solution. Instead, competitors in the small-medium market focus on a single sector or geography and on an assembler positioning which relies on partnerships inhibiting control over the project as well as achievable income.

In conclusion, from the competitor analysis, it emerges that the company is the only player providing "turnkey" solutions coupled with renewable energy solar without batteries. OSMOSUN value proposition is characterized by a wide range of standard solutions for all projects up to 50,000 m^3/day combined with the integration of solar energy. This allows it to overcome the plant capacity, sector and geographic constraints that characterize the desalination market while clearly differentiating itself from its competitors through its positioning as a provider of "turnkey" solutions coupled with solar energy. As a proof of adaptability to all contexts, installation of small units requires less than a week for a single person; larger projects may instead be installed by local partners who have been trained by OSMOSUN.

4 – FINANCING SDG 6 INVESTMENTS

4.1 – DESALINATED WATER PRICING

Water value and water cost

Over time, water has been recognized as an important commodity from both social and economic point of view. Although it is true that water has some common features that justify their importance for our society, it also has some special characteristics that make it even more valuable than other common commodities, especially in the pursue of sustainable development (Savenije, 2002):

- **Non-replaceable**: in case of scarcity, water can't be substituted by any other resource.
- **Renewable**: water resources are to some extent renewable and follow certain cyclic process in which it can neither be destroyed nor created; this characteristic varies in each region of the world;
- **Local**: in case of shortfalls, other commodities like oil can be managed in many parts of the world by transporting to the place of need due to its high monetary value for economic benefit; this may not be an attractive option for water transportation and therefore water issues are local in nature and are dealt with local water and energy sources.

Due to these peculiar characteristics, solutions like desalination plants or wastewater treatment match the need to solve water scarcity problems using local resources and facilities.

When it comes to valuing water, traditional economic accounting tends to acknowledge water values just the way most other products are valued, which is using the recorded price of water when economic transactions occur. In this case, the process is flawed by the fact that for water it is almost impossible to link its price to its value. Where water is priced, meaning consumers are charged for using it, the price often reflects attempts for cost recovery rather than value delivered. Still, economic valuation remains a relevant indicator, even though its application needs to be made more comprehensive (United Nations, 2021).

As noticed by Grafton et. al (2020), the characteristics of water as a commodity and the way in which this resource is governed give rise to what is defined as the "water pricing paradox": water price almost never equals its value and rarely covers its costs.

"Price almost never equals its value" refers to the fact that water, typically, cannot be transferred across competing uses where there are different marginal values. The second element of the paradox "price rarely covers its cost" arises from two factors:

- The **external cost** imposed on others stemming from water extraction, supply and treatment is, at best, only partially accounted for in the calculation of water supply costs;
- **Fixed costs**, such as the capital cost of water infrastructure, are, at best, only partially included in the water price charged in many countries. The difference is made up by transfers or subsidies to water suppliers that are, typically, paid from general revenues or taxes of local, state, or national governments.

The price paid by most water consumers is not a market price, but rather a regulated price determined by a water utility, regulator, or by government. Indeed, the low price for urban water services in many high-income cities means that water bills are, typically, a small proportion (less than 2 per cent) of most households' total expenditures.

Goals of water pricing

Adequate water pricing is prerequisite to stimulate large investments required for example by desalination plants, and water pricing requires a stable water governance as well as well-thought policies. As such, desalination is likely to emerge more because of, rather than as a tool for, regional cohesion and political stability.

A review published by Grafton et. al (2023) highlights the 4 goals of water pricing:

- **Full cost recovery**: the economic costs of the water supplied are paid for through the so-called 3Ts – tariffs, taxes, or transfers, and this is fundamental to give incentive to both invest in necessary additional infrastructure and maintain existing water infrastructure;
- **Efficient water price**: the price equals a transparent economic (including external costs) marginal cost of supply;
- **Equitable outcomes**: as many people as possible, regardless of income or circumstances, have their basic water needs met, and low-income households are not disadvantaged either in water access or in the price they pay for water;
- Water prices should incentive consumers to reduce water use when water is scarce.

Full cost recovery principle

Inside the European Union, the full cost recovery principle is a pillar of the Water Framework Directive (WFD), which came into force in 2000. Article 9 states that "Member States shall take account of the principle of recovery of the costs of water services, including environmental and resource costs […] and in accordance in particular with the polluter pays principle"

A key principle for water allocation to be 'efficient' is that the water price paid by users should be equal to the marginal economic cost of water supply, including both explicit components, (e.g. pumping and treatment) and implicit components (e.g. opportunity cost and environmental values). Fully incorporating all costs of water supply can provide welfare gains; nevertheless, water prices seek to achieve multiple social and political objectives (Chu, Grafton, 2021).

As reported by OECD (2016), over time it has been observed an increasing use of volumetric charges and the shift towards cost recovery: despite that, the focus of most water pricing schemes still aims at covering the long-run average cost of supplying water from existing water infrastructure (including up-front and O&M costs). The problem with such an approach is that it does not take into account the scarcity of water resources: prices do not reflect the full marginal social cost of using the resource.

While the theory of water pricing is straightforward, the practice is much more challenging. Water access is a primary necessity and governments have been reluctant to raise water prices in order to cover all costs. Alternatively, it has often time been chosen to subsidise water utilities: the main limitation here is represented by government budget constraints, which frequently result in subsidies not being sufficient. Thus, in many places in the world, water supply services are underprovided, even when consumers are willing to pay for improved water access, because returns from increasing water supplies or improving water services are not enough to cover actual costs at existing prices.

As discussed in chapter 1, water is considered a basic right and SDG 6 sets multiple targets which define water-related goals to be achieved. In practice, countries warrant access to water by utilizing specific regulations which result in different measures adopted, most often subsidized prices. Consequently, the costs of water are often borne by the society through taxes, transfers or cross-subsidization; in absence of such measures, a certain level of water stress in aquatic ecosystem is accepted in order to reduce the direct monetary price paid for water.

A study published by Pistocchi et.al (2020) underlines that, when assessing the cost of desalinated water, one must consider that it could be subsidized just as in the case of conventional water supply: therefore, its costs should not be compared with the production costs of conventional drinking water alone, but with its full costs instead. Even if desalination usually has a higher production cost than conventional resources, it has virtually no environmental cost if energy is decarbonized and brine disposal is appropriate, as it is demonstrated in the case of OSMOSUN. On the contrary, the authors report that cost of conventional resources abstractions in terms of water stress on ecosystems is seldom factored in.

The following tables show costs of municipal water supply (4.1) and transport of desalinated water (4.2).

Figure 4.1: Municipal water supply cost

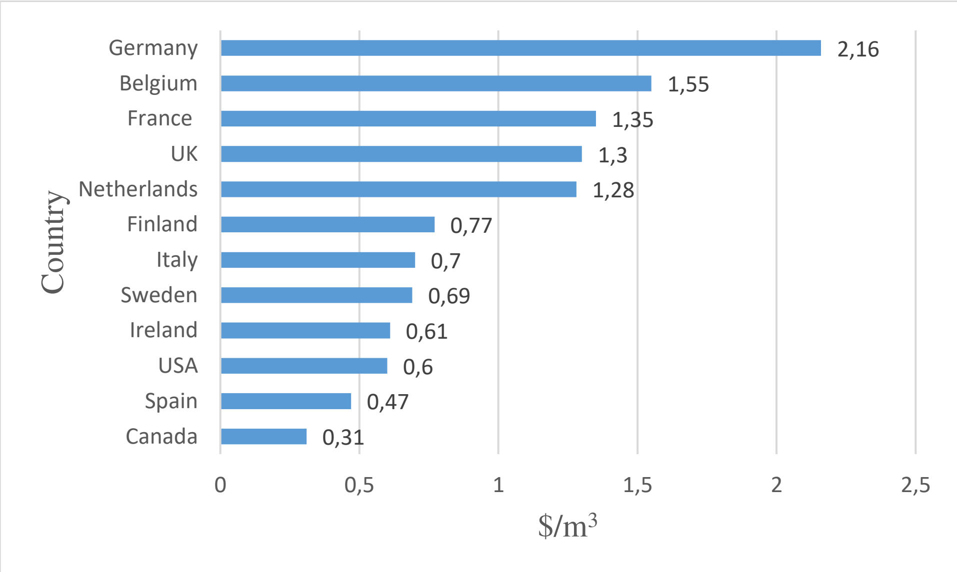
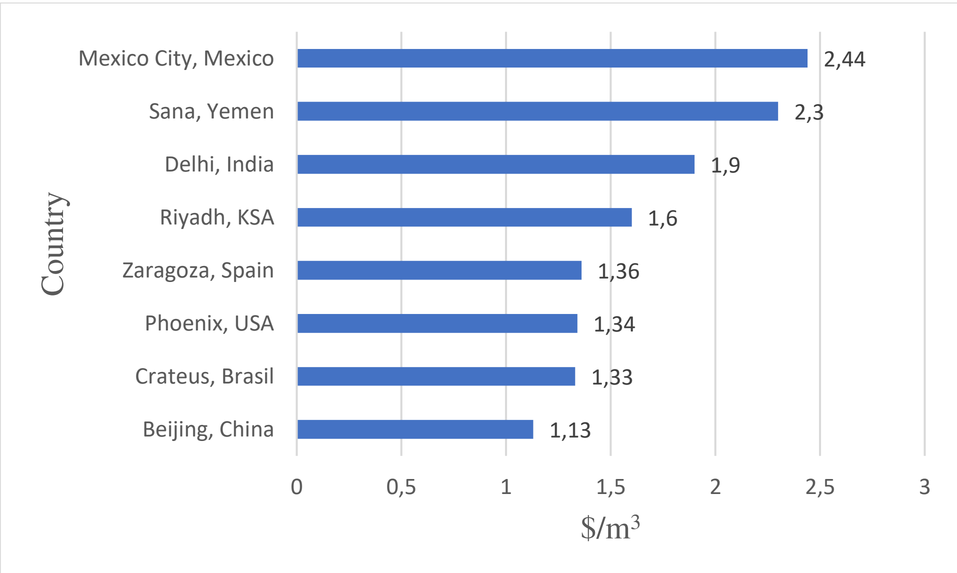


Figure 4.2: Transport of desalinated water cost



Source: Gude, 2016.

To carry out a proper analysis, it is necessary to put these numbers in the right perspective. First of all, municipal water supply costs vary according to how consumers are charged for the service they are provided with. Water tariffs pursue multiple objectives – including supply cost recovery, economic efficiency, accessibility, and affordability, some of which may conflict – and the outcome of these trade-offs is reflected in the final price for the users.

The governance of the country also influences water costs. However, there is no clear relationship between the wealth and the water costs of a nation. For example, the water costs for Gent, Belgium are 7.43 $\$/m^3$ in 2011 but the water prices in Egypt are $\$0.04/m^3$. The low water prices could possibly be related to low capital and labour costs in Egypt, even though Belgium has a GNP per capita which is 14 times higher than Egypt's.

Desalination is not a definitive solution suitable for every context: its convenience is mainly determined by the geographical characteristics of the area, as well as the ability to pay of inhabitants. Desalinated water price increases as the transportation distance increases; but above everything else, what dramatically increases transportation costs is the need to pump water vertically. In fact, highest costs of transport of desalinated water are recorded in Mexico City and Sana, two cities located well above 2000 meters.

Apart from urban contexts, successful examples of desalination projects can also be found in rural and isolated areas.

Real Projects

In the Sao Vicente Island, Cape Verde, OSMOSUN is present with "Desolsa" project involving the construction of a 20 m^3/day seawater solar desalination plant in Salamansa village. As shown in Chapter 3, the company specifically designs these units for autonomous operation in isolated sites with few technical and logistical infrastructures. The low maintenance needs and the absence of batteries guarantees a drinking water production cost of 1.5 €/m^3, which allows to improve living conditions of the existing population. Previous to this project, the village was facing a severe water stress with only 6 Liters of unsanitary water available per person per day, at the prohibitive price of 6€/m^3 (Ademe, 2018). This kind of project can be replicated in several isolated areas, especially in the Pacific and in the Caribbean region, helping to reduce the gap in water access for inhabitants of such areas.

Another case regards South Aegean islands in Greece. The analysis in carried out on three islands of different surface, Patmos (large), Lipsoi (medium) and Thirasia (small) belonging to Dodecanese and Cyclades archipelagos.

The case study, conducted by Mentis et.al. (2016) examines problematic water supply to these islands, with regard both to the water quality and quantity. While some water is supplied by private and municipal wells (primarily water of very low quality and high salinity) supplemented by rainwater collection (unreliable due to the intermittency of precipitation), water scarcity is mainly dealt with tanker vessels which transport vast amount of water from the mainland. At the same time island energy systems are congested and rely predominantly on fossil fuels, despite the abundant renewable energy potential, both for photovoltaic panels and wind turbines.

The cost for the Hellenic Ministry of Shipping is significant, e.g., 7.3 €/m^3 for Dodecanese cluster of 26 islands and 9.3 €/m^3 for the Cyclades cluster of 33 islands. As comparison, note that the cost in Athens is less than 0.70 €/ m^3, which is the price of water for household consumption 5 – 20 m^3 per month. There are also several desalination units in operation which absorb vast amounts of energy in already overloaded island energy systems.

The Hellenic Ministry of Transportation published a proposal regarding the construction of desalination units on the Greek islands and suggested that wherever possible the desalination units should cover their energy requirements from Renewable Energy. It is also stated that "applications for Renewable Energy Technology (RET) installations combined with desalination unit installation are a top priority as long as the RET nominal capacity does not exceed 125% of the desalination unit's power capacity". The electricity from RET is balanced on an hourly basis with the electricity demanded by the desalination unit. The electricity surplus is supplied to the grid at a maximum 20% of the produced power on an hourly basis.

In the light of existing law, three scenarios are analyzed:

- Priority to desalination:
- Priority to selling 20% of renewable energy to the grid;
- Priority to desalination, but also selling photovoltaic electricity up to 20% to the grid.

Results show that the water selling price ranges from 1.45 €/m^3 for the large island, while the corresponding value is about 2.6 €/m^3 for the small island, figures significantly lower than the current water cost (7 – 9 €/m^3). Selling prices are calculated in order to achieve an IRR of 16%, considered an IRR that satisfies both the public and the private sector. In conclusion, it is reported that "the water selling price is significantly lower than the price of transported water in all cases and the implementation of such a project would be beneficial for all involved stakeholders".

4.2 – MOBILIZING FINANCE FOR WATER-RELATED INVESTMENTS

Why water projects struggle to raise finance?

At this point, it should be clear that desalination technologies represent an underexploited solution to cope with water scarcity and sanitation problems that affect several areas all over the world. The final issue to discuss relates to the how these projects are financed, with a focus on the obstacles that may hinder investors from allocating resources into this sector.

Several elements are considered by investors before undertaking investments in water infrastructure projects: first and foremost, high upfront investments are required, especially for projects like large desalination plants; this initial cost is then repaid over a payback period, generating a cash flow stream which is not attractive to many investors. Then, as discussed in the previous paragraph, the water sector generally offers a low rate of return on investments due to regulations concerning water tariffs charged to consumers. Finally, when committing capital to a water infrastructure project investors face several risks which will be examined in the following sections.

Who finances water – related projects

Water-related investments are typically financed by repayable finance sources like debt or equity; raising capital is fundamental to cover significant upfront investments and will then be repaid through a combination of the aforementioned 3Ts - tariffs, taxes and transfers.
Depending on the risk appetite carried by each capital provider, the extent to which they will commit to investing in water projects will vary. Financiers can be classified in some major categories (OECD, 2016):

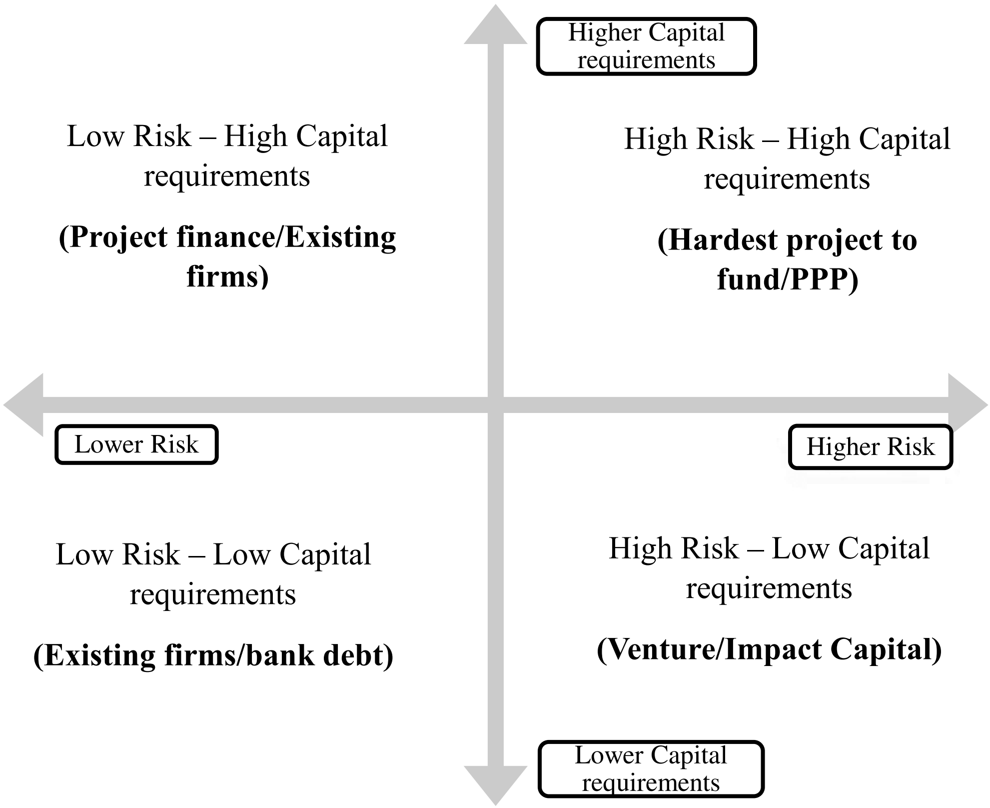
- **Private equity funds**: typically, private equity funds look for above-average returns on their investments. Although water is indeed a risky sector in which to commit capital, only a minority of water service providers worldwide meet the investing criteria of private equity funds. The main advantage offered by private equity funds is their role in reducing liquidity risk of original investors or lenders in the water sector either by offering a re-financing or a secondary market for infrastructure finance; they also represent a way for the original investors to exit. This function allows public entities to release capital tied up in water infrastructures and steer resources on new projects.

Some equity funds are specialised water funds, which solely invest in the water sector. Hence, they are more prone to take the risks associated with this sector, even though they expect higher returns which are difficult to realize. These thematic funds are often established by high-net worth individuals.

- **Institutional investors/Pension funds**: they have a limited engagement in the water sector, coherently with their limited appetite for risk and their expectations for a consistent level of returns. According to OECD data, thanks to improved grasp f the risks associated with infrastructure lending, institutional investors are committing to investments that boast higher yields, as well as comparatively low default rates and better recovery rates, than those similarly rated corporate debt.
- **Commercial banks**: they are mainly attracted by low-return and low-risk water investments, which are only fund in developed countries. To their eyes, similar projects in developing countries are less appealing due to higher risk level. Commercial banks also give value to short maturities due to their constant necessity to adjust investment strategies over time.
- **International Financial Institutions (IFIs):** they offer favourable terms for debt financing and often will accept lower returns than commercial banks and insurance companies. IFIs deploy a wide a range of skills which include also advisory services and technical assistance. Their main function is to leverage funding from other market players. Due to increasing competition from other financiers, they have a growing need to tailor their products to fill in gaps in the market;
- **Philanthropists**: Many philanthropic funds also offer loans and grants to the water sector. These funds are often managed by NGOs and represent an important source of capital for developing countries. Philanthropic donations or loans to development programmes are estimated to be of a similar order of magnitude to total overseas development assistance (ODA).

The following graphic classifies capital providers basing on their risk appetite and capital requirements in which they tend to be involved and it is useful to break down the investor spectrum into more detail.

Figure 4.3: Risk – Capital requirements framework



Source: Mazzucato, Semieniuk, 2018.

For the purposes of this thesis, the focus is on investors operating in the top – right and bottom – right areas, characterized by higher risks level which are typical of developing countries.

Public financial actors tend to occupy the top-right quadrant, which plays a critical role in creating and shaping new markets to crowd in private capital. This means that public sector investment or policy initiatives should be finalized not only at financing and favouring certain projects, but they should also be designed to attract and stimulate additional private sector investments.

As the World Water Council (2018) brings up, a core argument is that it is not possible to solve the water infrastructure financing challenge just by simply more capital. Project success depends on other factors as well, such as contracting model adequacy and efficient and transparent tendering processes. Besides, it is crucial that a country's infrastructure strategy is connected to its socio-economic objectives.

For example, Morocco has prepared a National Water Plan 2020 – 2050 which sets different objectives and aims to triple its desalination capacity by 2030 by building nine new plants to address water scarcity and climate change. The government estimates that 40 billion of investments are needed and intends to use Public – Private Partnerships (PPP) to crowd in the private sector, which may contribute with 85% of investments (IMF, 2023). In 2020, a new PPP law entered into force to create a favourable regulatory environment for investors.

Similarly, Mazzucato (2023) notes that “unlocking finance for development requires recognizing that a central issue is not only the lack of finance but how it is utilized in dysfunctional manners”: the main critics point out that it is too short-term, it leans more towards ‘brown’ than ‘green’ investments, is not reinvested in the real economy but is used for other financial purposes and evades taxation. Financing for development, especially for the SDGs, can be improved with policies that address all these challenges. It also suggests that “there is no reason why the SDGs cannot benefit from a mission-oriented approach that puts urgency, fairness and collective investment at the core of the partnership”. To this end, a particular financing scheme that is being increasingly used is blended finance.

Blended finance

Blended finance is a financing structure defined by the OECD as the “strategic use of development finance for the mobilisation of additional finance towards sustainable development in developing countries”. This is a useful definition as it introduces ‘additional finance’ as private finance that does not have an explicit development purpose; and ‘development finance’ as both public and private finance that is being deployed with a development mandate. Therefore, this framing distinguishes finance by purpose rather than by source.

Although it can consist of different elements, the concept of blending revolves around three pillars (CEBRI, 2023):

- The leverage of capital;
- Positive socio-environmental impact;
- Balance of risks and financial return.

From these pillars, operations should be designed considering the perspectives of the sources of funds and the parties involved, financial structures and the use of resources.

Blended finance represents therefore a way that allows governments to crowd in private players. Referring to the previous risk – capital intensity framework, public players can stimulate intervention from the private sector by using Public – Private – Partnerships (PPPs) especially for large projects or by utilizing blended finance as a mechanism to finance smaller and less capital-intensive projects.

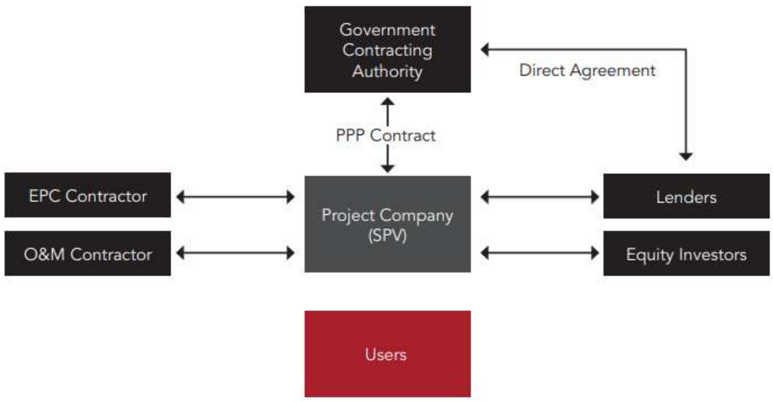
4.3 – PUBLIC – PRIVATE PARTNERSHIPS

The traditional way in which governments operate consists in financing capital costs with debt, which is than repaid using the 3Ts. This debt financing approach spreads out the costs of the project to match the useful life of the asset, usually a time period no shorter than 20 to 30 years. Many governments, pushed by the rising cost of construction and a competitive fiscal environment for governments, have turned to non-traditional financial innovation.

Public – private partnerships (PPPs) have grown in popularity as a method to leverage private sector actors in the production of government services. PPPs are becoming more common for large scale water infrastructure projects to address the global challenge of global scarcity. The World Bank defines PPPs as “a long-term contract between a private party and a government entity, for providing a public asset or service, in which the private party bears significant risk-management responsibility and remuneration is linked to performance”.

With respect to a situation where only one entity is in charge for the project, pooling resources across sectors is beneficial for the realization of the project because each party can focus on selected aspects over which it has a comparative advantage, such as technical expertise, capital raising, information, personnel, and management.

Figure 4.4: Typical PPP Project structure



Source: World Bank (2017)

Usually, the private party is a Special Purpose Vehicle (SPV) which is set up for the specific purpose of the project and is financed by a combination of debt and equity. The PPP contract is the contractual agreement between the private party and the government, in which the private party assumes a certain degree of risks for the realization of the project. Government may also have a direct agreement with lenders concerning step-in rights or debt repayments guarantees. On the other hand, the project company may sign sub-contracts for specific phases of the project i.e. O&M.

PPP contracts are mechanisms to transfer risks from public agencies to private firms as an attempt to improve operations and reduce operating costs, with the ultimate goal of maximizing "value for money". Thanks to PPP arrangements, public institutions face a reduced financial burden especially in the design and construction stage of a project, thus relieving stress from public debt. The private side, on the other hand, may accept to bear these risks if a profit motive exists; therefore, the type of risk and the extent to which it is shared is a critical component of PPPs that needs to be understood by policymakers and public managers (Greer, 2021).

PPP arrangements for large and complex infrastructure projects combine competitive tendering and negotiation processes to improve efficiency and monitor and allocate risks between the public and private sectors.

Overall, a PPP can be categorised into one of three groups (Lima et.al, 2021):

- **Assets involved**: projects can be divided into building from scratch (i.e., greenfield) or rehabilitating and upgrading (i.e., brownfield) infrastructure.
- **Risk allocation**: this classification is centred on the responsibilities allocated to private parties with regard to design, construction or rehabilitation, finance, maintenance and operation;
- **Remuneration**: this group focuses on how the private parties are paid, either by direct consumers, the government, or both.

As anticipated in Chapter 3, there are several procurement models that can be contracted between public and private actors. For this analysis, the most significant classification is the one which focuses on the risks that are transferred from public sector authority to private sector authority, which ultimately define the PPP arrangement type.

Firstly, since risk allocation has a direct impact on the pricing of a PPP, it is important to identify the main risks to be able to assess whether an investment is likely to be feasible and perceived as fair. The analysis also helps in evaluating whether the project is affordable for taxpayers and consumers, but also able to raise capital from the private sector. Here, main risks in water desalination PPP projects are reported, as well as the entity which typically faces that risk. The list doesn't intend to be exhaustive (Global Infrastructure Hub, 2019).

- **Land availability, access and site risk**: The main risk factors are associated to selecting land suitable for the project, providing it with good title and free of encumbrances, addressing indigenous rights, obtaining necessary planning approvals, providing access to the site, guaranteeing site security.
- **Social risk**: public entity or shared risk. It concerns the project impact on the marine environment, adjacent properties and affected people (including public protest and unrest) but also resettlement and industrial action.
- **Environmental risk**: private entity bears this risk or shares it with public entity. This risk is associated with pre-existing conditions, obtaining consents, complying with laws, dealing with conditions caused by the project and also takes into account external events, climate change and marine environment events (e.g. algae blooms).
- **Design risk**: private party bears this risk, which include design not suitable for the purpose required, approval of design and changes from original design.
- **Construction risk**: The Private Partner typically assumes the risk of cost increases to the extent these are not caused by compensation events (such as in relation to unsurveyed site conditions) or MAGA events. The risks concern construction costs exceeding modelled costs, delays in completion, project management, interface, quality standards compliance, health and safety, defects, intellectual property rights compliance and industrial action. In certain markets, risk is considered manageable by the Private Partner through robust pass through of obligations to credible and experienced subcontractors and by allowing appropriate timetable and budget contingency.
- **Power supply**: Desalination requires a significant amount of power, and the Contracting Authority is typically responsible for providing the required power (and bearing the risk of any increase in power prices) unless the project is developed as a combined power and water project. In emerging markets or markets where the electricity grid is not sufficiently robust, this places a significant amount of risk on the Contracting Authority. Alternatively, the Private Partner may enter into a power supply contract with a separate power supplier (in emerging markets it will usually be state-owned). The Private Partner will pay the supplier for power delivered, but the costs of power supply will be a passthrough cost under the PPP contract.
- **Operating risk**: private entity bears this risk. Operating risk relates to events affecting performance or increasing costs beyond modelled costs, performance standards and price, availability of resources (other than power, where not combined power and

desalination), intellectual property rights compliance, health and safety, compliance with maintenance standards;

- **Reliance on key membrane supply sub-contract** (if using reverse osmosis technology): membranes need to be replaced on a comparatively regular basis during the life of the project. Membrane supply is comparatively specialised and this can leave the Private Partner/the project exposed should the chosen membrane supplier fail to perform or cease to exist.
- **Demand risk**: The risk that demand for potable water is not sufficient to utilise the full production capacity of the project. As explained above, demand risk is typically on the public entity which commits to buy a minimum amount of water even if demand is lower.

Aside from this project-specific risks, there are few risks that are typically shared by nature:

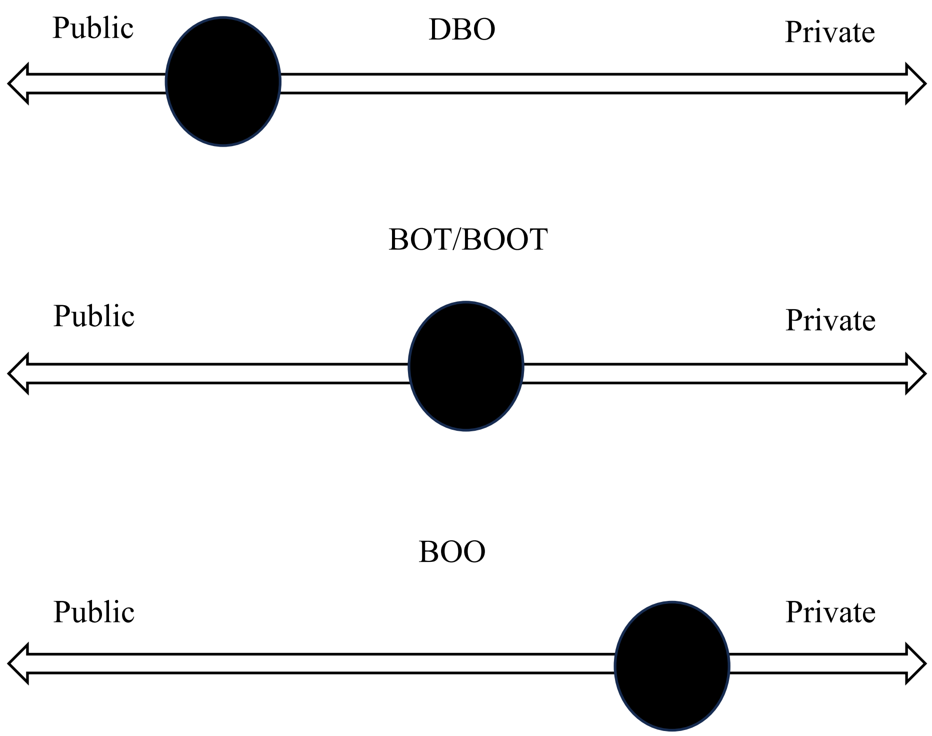
- **Financial risk**: Private partner bears the risk of construction costs increase due to inflation and will generally price this risk in markets where it is possible to quantify it. Where this is not possible, the Contracting Authority is likely to be asked to bear some risk the project. Financial risk also includes commercial risk that arises when the revenues from the service are lower than expected: this might happen because the service is not appropriately charged, because there is a low willingness to pay or due to a weak capacity to collect revenues. Stable regulatory frameworks, robust business models, pricing schemes, and enforcement capacities help address this risk.
- **Foreign exchange risk**: foreign exchange risk mainly affects projects in the case where capital is provided in a currency while revenues are generated in different currencies. This risk can be addressed by developing domestic financial markets, which can generate financial resources to invest in water security and sustainable growth. Opportunities are growing as emerging economies keep developing;
- **Partnering risk:** The risk of the Private Partner and/or its sub-contractors not being the right choice to deliver the project, Contracting Authority intervention in the project, ownership changes and disputes.
- **Disruptive technology risk**: The risk that unexpected events occur that are beyond the control of the parties and delay or prevent performance.
- **Force majeure risk**: The risk that unexpected events occur that are beyond the control of the parties and delay or prevent performance.

Finally, a correct risk evaluation also considers general risks which may occur during a complex and long-lasting project:

- **MAGA Risk** (public risk): MAGA is an acronym for Material Adverse Government Action. It refers to the risk of actions within the public sector's responsibility having an adverse effect on the project or the Private Partner.
- **Change in law risk** (public risk): The risk of changes in law affecting performance of the project or the Private Partner's costs.
- **Early termination risk** (shared risk): The risk of a project being terminated before its natural expiry on various grounds, including the financial consequences of such termination and the strength of the Contracting Authority's payment covenant;
- **Condition at handback risk** (private risk): The risk of deterioration of the project assets/land during the life of the PPP and the risk that the project assets/land are not in the contractually required condition at the time of handback to the Contracting Authority.

Procurement models

Fig 4.5: Risk sharing in DBO, BOT/BOOT and BOO contracting model



Source: Greer et. al (2021).

Each arrangement type is associated with different project risk.

The Design-Build-Operate (DBO) is a relatively simple arrangement in which the public entity owns and finances the construction, while the private entity designs, builds, and operates the asset to an agreed level of output. These are similar to another PPP type sometimes referred to as a Build-Transfer-Operate (BTO). The private entity, which is also the operator, takes minimal financing risk and is paid a fixed amount for the design and construction at set time periods or milestones. The private operator does have responsibility for replacing parts and equipment, but their financial documentation and disclosure requirements are limited.

A relatively new PPP type that has grown in popularity is the Build-Operate-Transfer (BOT) arrangement, in which private entities assuming risks in design, finance, construct, operation, and maintenance phases of a project for public use for a specific term during which they are able to collect revenue from the facility. Then when the contract term ends, the title and ownership goes back to the government. In this timespan, the private entity expects to collect user fees to repay its initial investment and realize a profit.

The Build-Own-Operate-Transfer (BOOT) is a similar arrangement, in which the private entity also owns the asset prior to transferring it to the public entity. Another variation is the Design-Build-Own-Operate-Transfer (DBOOT) where, in addition to other functions, the same private entity is responsible for designing the facility.

Shifting towards the private side, a PPP arrangement that comes closest to actual contracting-out of the public service is the Build-Own-Operate (BOO) arrangement. In this model, a government entity sells the rights to build a project to a private firm with the requirement that design specifications are met. The firms are then allowed to control operations for the remainder of the project. From the public perspective, the main advantage is that the local government timely recovers the investments costs; the main disadvantage, which also represents the main incentive for the private player, is that the project company assumes the control of the asset for the remainder of its useful life.

Pros and Cons of PPPs

As reported by Marques (2018), in the project preparation before the public tender stage, PPPs studies are carried out: this improves the knowledge and quality of the project, compared to traditional public procurement. In the public tender stage, most of the public tenders comprise several competitive stages, including a negotiation stage and a best and final offer (BAFO) with one or two competitors, reducing the possibility of over profits or excessive rents. Finally, at the contract execution stage, the private sector continues to use its know-how and to innovate to meet and exceed the targets defined in the contract, resulting in a greater value for money of the PPP project.

As a rule, the contract pays per performance (output-oriented approach instead of input oriented as is common in public works) and the public entity is obliged to buy a minimum amount of output from the private player, even if the demand is lower than the minimum output.

However, the reality shows that PPPs are not always so successful. There are many examples of contracts that have failed to provide the expected value for money: in this case, contracts are renegotiated, leading to a worsening the financial conditions for the public sector and several have been subject to an early termination. Conflicts and occasionally litigation are also usual, and the quality of service is sometimes underperforming.

In conclusion, if too much risk is allocated to the private party, lenders will reduce the amount they are prepared to lend, meaning that more equity will be needed. To avoid these failures, procurement models must be chosen in accordance with risks assessed, consumer willingness to pay and service charging mechanisms.

4.4 – PRIVATE SECTOR INVESTORS

Referring to the risk – capital intensity framework, this last part focuses on those investors that are willing to commit capital to water-related projects, especially those in developing countries which are in general characterized by higher risk and, when related to rural communities, by lower capital intensity.

The objective is to understand in which areas the buy-side players invest, to which extent and what prevents them from providing the additional capital that initial public sector investments aim at mobilizing. To this purpose, a set of 122 investors has been extracted from S&P Capital IQ database basing on criteria such as their impact on climate change adaptation and mitigation and focus on SDG 6 and 7.

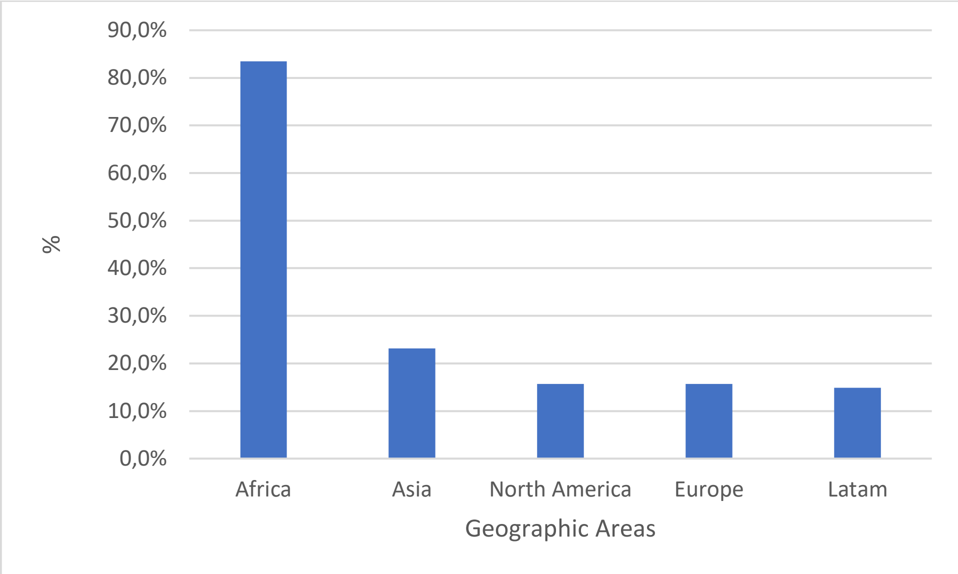
Before moving on, we briefly introduce impact-oriented investors, which fulfil an important role in this specific investment category. Impact investment can be defined as investments made into companies, organisations and funds with the intention to generate an economic and social impact alongside a financial return.
By using appetite for risk of each investor, we can classify them into three categories (World Water Council, 2018):

- **Impact investors**: they are the most willing to accept a financial return that is below the market rate, provided that the social or environmental impact associated with the investment meets their criteria;
- **Opportunistic investors**: they are only interested to a certain extent in impact investing, and therefore require a higher rate of return than pure impact investors, although still below the market rate;
- **Mainstream investors**: they are not explicitly focused on impact and target a market rate of return, adjusted for the associated risk.

According to this taxonomy, impact investors accept the risk of first loss and in doing so they provide some protection to opportunist investors. Similarly, investment is de-risked for mainstream investors, because opportunist investors have accepted the risk of 'second loss'; that is, losses that go beyond the capacity of impact investors.

In this section, results are presented and commented. The selected investors have been classified by type and analysed with respect to their investing themes, geographic areas covered, investing stage and investing instruments, as well as their contribution to SDGs, in particular SDG 6 and 7.

Figure 4.6: Geographic Areas

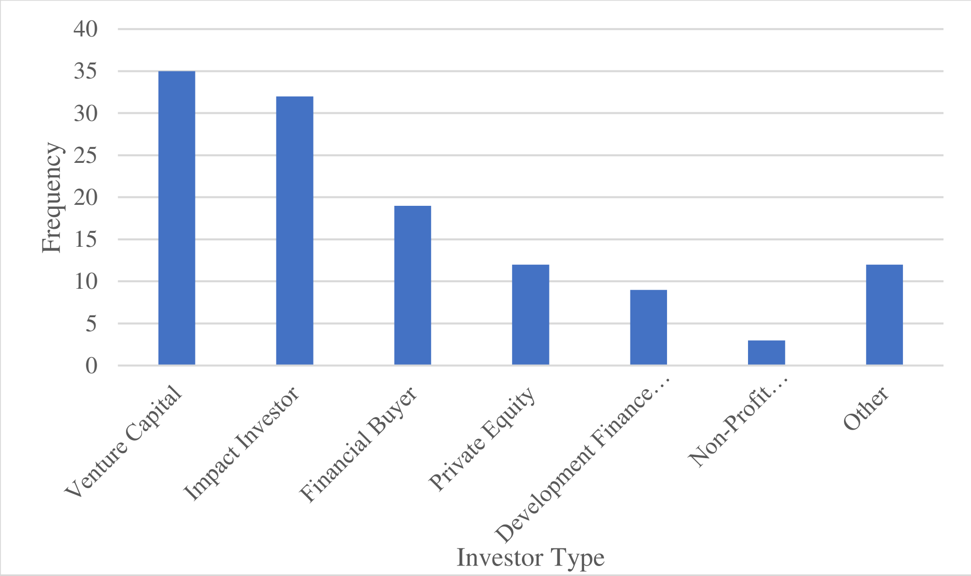


Source: Personal Elaboration on S&P Capital IQ investors list

Taking a look at the geographies in which investors decide to commit their capital, we observe that the most popular region is Africa (84%) followed by Asia (23%), while all other regions are addressed by about 15% of investors. Depending on the dimension and mandate of each investor, it is possible to distinguish between investors which are interested in a single geographic area (55%) and investors who focus on two or more areas (45%). Among the 67 investors who target a single area, the vast majority focuses on Africa (59), confirming that several investors see in this area the greatest development opportunities. Going in further detail, it is observed that 19 investors specifically focus on Sub-Saharan Africa and 15 of them are based in Africa, highlighting again the importance of relying on local institutions with specific development mandates and knowledge of the current political and administrative situation.

A report published by the Global Impact Investing Network (GIIN, 2023) asked to a sample of 308 impact investors in which geographic area they plan to increase their allocations: Sub-Saharan Africa (56%), Latam (48%) South-East Asia (42%) and South-Asia (40%) result as the regions of major interest; only 2 – 5% of investors intend to decrease their assets in such regions. In developed markets like Western&Southern Europe and US&Canada, the majority of investors (57% and 66%, respectively) declares the intention to maintain existing assets.

Figure 4.7: Investor Type



Source: Personal Elaboration on S&P Capital IQ investors list

From the analysis, it emerges that Venture Capitalist and Impact Investors are the most frequent investor type (35 and 32 respectively), followed by Financial Buyers, Private Equity and Development Finance Institutions (DFIs). DFIs distinctive characteristic is their public nature, as they are typically owned by national governments or supranational institutions with the mandate of investing in strategically relevant sectors. The residual voice "others" represents nearly 10% of the sample and includes different actors such as advisory and consulting firms, matching platforms and philanthropic funds: the latter may have an impact-oriented mandate and are especially relevant in the water sector, in order to provide capital for projects with below-market returns.

DFIs are particularly important in Africa because they provide capital in countries with undeveloped or developing financial markets; this is possible because they can accept lower returns and are willing to undertake patient investments due to their longer investment horizon. Furthermore, these institutions are backed by national governments: this means that they have the structure necessary to deal with other countries and to provide services that are often times lacking in the countries which benefit from these investments, especially on the administrative and political side.

The World Bank Group is the biggest DFI in the world and operates through five major institutions, including the International Bank for Reconstruction and Development (IBRD) which lends to governments of middle-income and creditworthy low-income countries, the International Development Association (IDA) which provides financing on concessional terms to governments of the poorest countries and the International Finance Cooperation (IFC) which provides support through loans, guarantees, equity and mobilizes additional capital from other sources to grow private sector investment in developing countries. In 2023, 40% of total commitments of IBRD and IDA were allocated to climate finance, corresponding to $29.4 billion (World Bank, 2023).

These institutions are mainly funded by contributions from high- and middle-income partner countries, transfers from other Bank Group institutions, borrowers' repayments of earlier IDA credits and funding raised in the capital markets.

DFIs in the sample include also the European Investment Bank (EIB) and the New Development Bank (NDB) which are arising from a supra-national institution (the European Union) or from countries that are joining forces to strengthen their development process (BRICS countries). Other DFIs are owned by governments such as the British International Investments (BII) or FinDevCanada, a wholly owned subsidiary of Export Development Canada (EDC), which is Canada's Export Credit Agency. Finally, we have the Dutch Entrepreneurial Development Bank (FMO) whose major shareholder is the Dutch state itself (51%) while the remaining part is owned by commercial banks, trade unions and other private sector players.

Since they are owned by wealthy developed countries, these DFIs have a global scale and are able to invest across various geographies and sectors; other DFIs have a limited geographical scope. This is the case of InfraCo Africa, which focuses on building infrastructure in Sub-Saharan Africa. Given the high capital requirements of these projects, InfraCo Africa receives funding through the Private Infrastructure Development Group (PIDG), which is a pioneering infrastructure development and finance organisation funded by governments of the UK, the Netherlands, Sweden, Switzerland, Canada and Australia as well as the IFC.

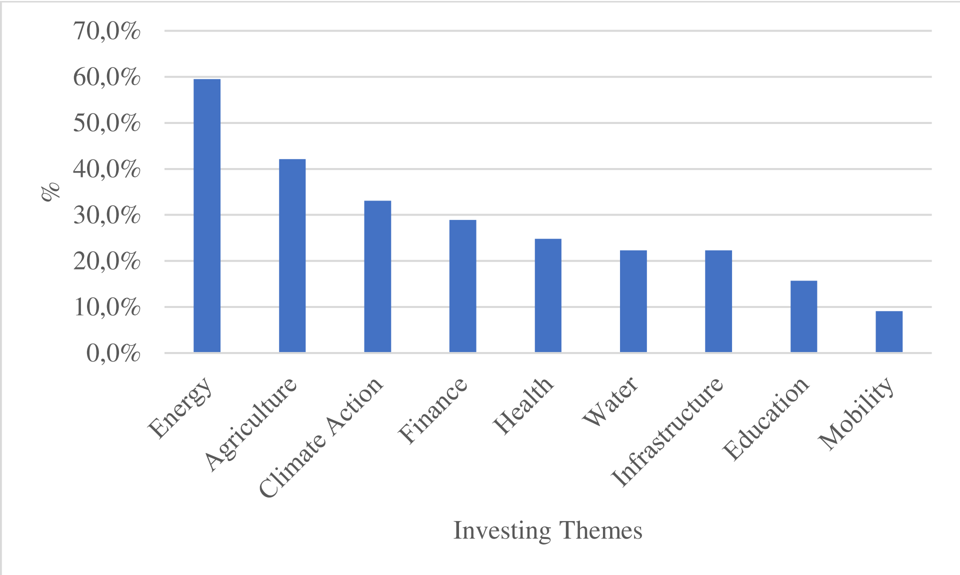
Importance of DFIs goes beyond their role as projects financiers. When these institutions provide capital, either directly or through local investors, they are playing a crucial role in steering the development of emerging economies, as the choices in terms of capital allocation are able to shape local markets, especially in areas where the lack of financing is impeding infrastructure development and access to basic services.

Looking at DFIs' portfolios, what stands out is that they invest in several other thematic investors included in the sample. It is the case of FinDevCanada, which invests in the AIIF 4 Fund owned by African Infrastructure Investment Manager and Alitheia; EIB invests in Acre Impact Capital, AIIF 4, Vantage Mezzanine, Partech Partners, AfricInvest, ARCH Emerging

Markets Partners, Metier Sustainable Capital, Novastar Ventures, GroFin; FMO invested in Acumen Resilient Agriculture Fund and Metier Sustainable Capital

These funds differ by size and investing themes, which span from climate infrastructure, agriculture, renewable energy and water to health, education and fintech. The common trait is represented by the geographical scope as almost all these funds invest solely in Africa.

Figure 4.8: Investing Themes



Source: Personal Elaboration on S&P Capital IQ investors list

From the graphic above, it emerges that the buy-side interest is spread among multiple investing themes, the most common being Energy (60%) followed by Agriculture (42%) and Climate Action (33%). About one quarter of investors are interested in Health, Water, Infrastructure. Even though these numbers show a clear preference for some investing areas, it is important to keep in mind that strong interdependencies exist among these investing themes, as investing in a sector generates direct or indirect impacts in other sectors: for example, infrastructure investments often times concentrate in enhancing energy supply; similarly, fintech investments may aim at helping access to small capital for farmers, and water investments often take place as a response to climate change. For example, FMO invested in Acumen Resilient Agriculture Fund (ARAF) which aims at making agriculture sustainable and resilient to climate change, especially for smallholder farmers.

Therefore, investing themes can be seen as macro categories which contain several sectors: basing on selection criteria, these investors are active in sector with a positive impact on SDGs. For example, investments on energy refer to renewable energies, often related to solar home systems and mini-grids for rural communities. Agriculture investments mainly relate to microfinancing for small farmers and technologic solutions to improve productivity, ultimately contributing to securing the agribusiness value chain. Other investors focus on sustainable mobility, waste management and digital platforms to ensure first access to education and health.

Investing Stage and Instruments

Coherently with sample selection criteria and preferred geographic areas, investors display a clear preference for start-up and early-stage investments (78%), followed by investments in growing companies (49%) and late-stage investments (20%). As far as investment instruments are concerned, 94% of investors undertake equity investments, while 28% invest through debt. Grants and guarantees are mainly utilized by philanthropic funds and development finance institutions.

Although only few investors disclose the amount of asset under management (AUM), it is worth noting that huge differences in size exist, ranging from USD 10 – 50 million up to USD 5 – 10 billion for larger investors. This characteristic is confirmed by a 2023 report from Global Impact Investing Network (GIIN), which analysed a sample of 308 impact investors from all over the world managing in total USD 371 billion; it emerged that the five largest organizations in the sample accounted for 47% of AUM.

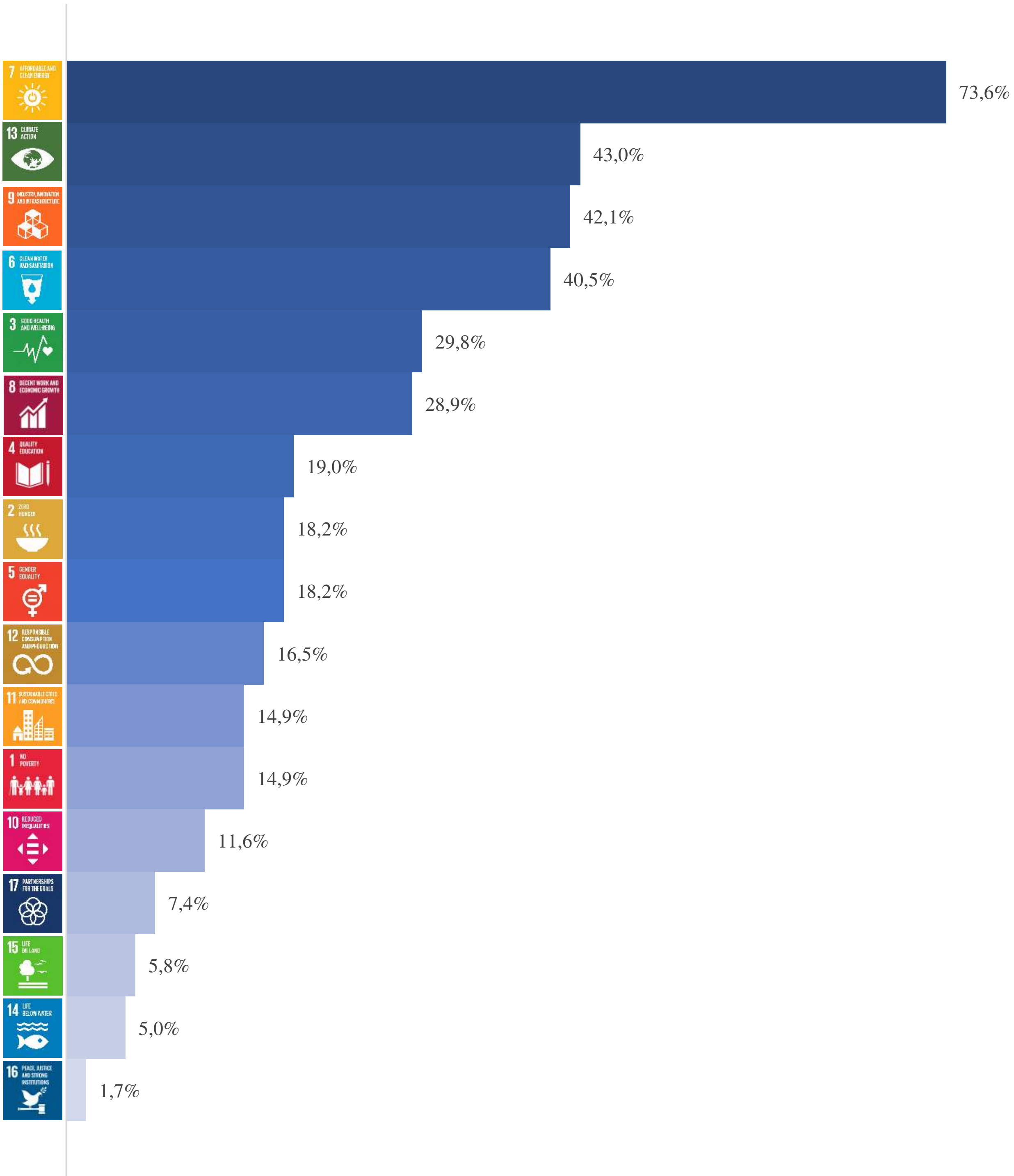
Larger investors are involved in multiple stages of a company's life cycle, spanning from seed capital to mature companies and even restructuring and turnaround operations. They have the ability to invest heavily in public equity and public debt, while other divisions are dedicated to private capital investments; conversely, many smaller investors tend to focus only on seed and early-stage financing to promote innovative companies, especially in Africa, with ticket size ranging from around USD 50 K up to USD 5 – 10 million.

SDG

As already seen, different types of investors are included in the sample. The common trait is that their investment mandate is influenced, to a greater or lesser degree, by the objective to pursue certain impact goals. This is particularly true for impact investors, which public detailed report on their impact objectives and how they intend to achieve them. In fact, as reported by the GIIN in a dedicated report, 76% of impact investors relies on SDGs to guide impact priorities and set impact targets.

Usually, investors contribute directly to one or more SDGs, but their activity has an indirect impact on other SDGs as well. In particular, SDG 5 (gender equality), SDG 8 (decent work and economic growth) and SDG 13 (climate action) are cross-sectoral and can be affected by very diverse investing themes.

Figure 4.9: Percentage of investors contributing to each SDG



Source: Personal Elaboration on S&P Capital IQ investors list

Overall, SDG 7 (Affordable and Clean Energy) is the most addressed by investors, while SDG 6 (Clean Water and Sanitation) is targeted by 40% of investors. Of course, this predominance is intrinsic in the sample since investors have been selected basing on their interest on renewable

energy and water access. SDG 13 (Climate action) and 9 (Industry, Innovation and Infrastructure) are mentioned by around 40% of investors; health and education (SDG 3 and 4) are also a priority for several investors.
Renewable energy sector attracts almost three-quarters of investors and is by far the most attractive sector. Indeed, it is a mature and established field of investment, as over the years technological innovations improved efficiency and reliability of installed systems.

Focusing on the 49 investors who target SDG 6 contribution, the first thing that stands out is the fact that 50% of impact investors address water and sanitation topics, as well as 6 out of 9 DFIs and 2 out of 3 Non-Profit Organizations, confirming the importance of investors who accept below-market returns given the difficulties in financing water projects.

Water investments are mostly concentrated on seed and early stage. A study conducted by the GIIN (2023) on emerging trends in impact investment highlights that most investors operating in the energy (69%), agriculture (60%) infrastructure (59%), and water (56%) sector are willing to increase their impact assets; only 2 – 3% plan to decrease their assets in such areas. In particular, 71% of water sector investors targeting emerging markets are planning to increase their allocations, compared to 41% in developed markets, proving once again that investors recognize the need and the opportunities brought by countries in which even basic services are still lacking.

As previously seen, each investing theme includes several sectors in which investors can commit their capital: with respect to water-related investments, the EIB is actively involved in projects addressing municipal water supply systems, rural water supply, water management, water transportation, distribution networks, desalination and wastewater treatment, sewerage, low-scale sanitation and hygiene measures. Similarly, NDB focuses on water supply infrastructure to provide clean water access in BRICS and Emerging Market economies and Developing Countries (EMDCs) – which include since 2021 Egypt, Uruguay, United Arab Emirates and Bangladesh.

Large DFIs offer direct support by undertaking joint projects with governments to provide large and complex infrastructure which are often times part of a national plan; it is the case of certain World Bank projects addressing access to clean water, flood prevention, or scaling up smallholder farmers by managing and improving irrigation systems. Alternatively, DFIs contribute indirectly by investing in thematic funds which have specific mandate to find and execute smaller-scale and local projects.

As an example, among investors in the sample we have Incofin Investment Management, an impact investor based in Belgium who launched in 2023 the Water Access Acceleration Fund (W2AF), a private equity fund with focuses on improving access to safe drinking water which raised €70 million of capital commitments. This fund was created as a response to increasing financing needs of private companies offering innovative solutions to provide safe drinking water, such as desalination and wastewater treatment. It is a blended finance arrangement and capital providers include the EIB, which contributed with €10 million. Thanks to the presence of public investors, the fund aims to mitigate first-loss risks and to stimulate additional private sector investments.

It is also worth mentioning that Green Tech Capital, a Venture Capitalist from Germany, invested in Boreal Light, which is a company that operates in solar desalination just like OSMOSUN. Some other private investors participate in PPP Projects.
Finally, SDG 6 investors include Water Finance Coalition and Water Resilience Coalition, two institutions which raise awareness on water access matter and deploy patient capital. Another major institution is Water.org which relies on philanthropic investing.

The presence of such players is a distinguishing trait of the water sector: for many reasons that have been analysed in this thesis, such as water pricing and project-specific features of desalination plant, it is difficult to implement a univocal standard for water projects that can be replicated for widely differing contexts. This represents a major distinction between SDG 6 and 7 investments because in the renewable energy sector this sort of scalable replication is one of the reasons that has permitted to reach maturity and to significantly lower risks, thus attracting the interest of both impact and commercial investors.

While academic theory mainly focuses on the role of public funding for SDGs, the reality is that their key role should be to stimulate additional private sector investment, which are essential to meet the capital requirements needed to pursue SDG objectives.
In developing countries, such strategic finance is provided by development institutions, either with a global scope, like the World Bank or the European Investment Bank, or with a regional remit mandate such as the African Development Bank (AfDB), the Asian Development Bank (ADB), the Inter-American Development Bank (IDB).

When public financial institutions, such as development banks, act as mission-driven investors, they often act as lead investors (lenders of first resort) which implies assuming various types of risk; in doing so, they allow several private investors to enter the market, from venture capitalist and private equity to impact investors with explicit focus on SDG impact.

CONCLUSION

The estimated cost necessary to reach the Sustainable Development Goal 6 by 2030 is quantified in USD $1 trillion per year, roughly equivalent to 1.2% of global GDP. In particular, achieving equitable access to safe drinking water for all by 2030 requires tripling current investment levels.

In this scenario, the water scarcity challenge needs to be tackled not only to meet SDG 6 goals, but also because restoring and preserving the hydrological cycle is a crucial aspect to progress with climate change mitigation and adaptation, as well as securing food and energy for everyone.

Therefore, water should be considered not only as a stand-alone sector but also as a connector: this requires a shift in mentality by the international community at all levels, from governments to regulators and investors. The enabling environment is particularly important, as there needs to be a sound system of incentives which limits the current trend of over-consuming water in several sectors without taking into account the externalities generated by this behaviour.

Despite the speed at which the context evolves, what remains clear is that without severe intervention the water stress is surely going to worsen, both because of population growth in developing countries and climate change effects. An ever-growing response is represented by desalination, which is a booming market that is attracting the attention of countries and policymakers in designing and implementing national strategies to secure their water resources.

This has been possible thanks to a long-term development occurred in the sector, starting from the 60s of past century allowing to lower costs of desalinated water and to come up with multiple cycles of technological innovation and process improvements, ultimately leading to the present situation in which reverse osmosis has established as the leading technology in the market. Despite huge progress have been made, several new technologies are under consideration, in light of the increasing demand for desalinated water and the unavoidable attention that has to be paid to environmental issues.

Even though desalination market is experiencing a strong growth, pursuing SDG 6 objectives requires that basic drinking and sanitation services are provided not only to large cities (i.e. cities in Middle East countries) but also to rural and isolated communities. Due to its intrinsic nature, water is generally an undervalued and underpriced resource, resulting in a poor record of cost recovery for water investments. For these reasons, water utilities rarely generate strong revenue stream, making it more difficult to mobilise the private sector.

To this end, strong cooperation across all stakeholders is fundamental to bridge the existing financing gap and to raise capital to realize water-related investments. When traditional commercial finance falls short due to high risks and substantial upfront investments, a joint approach between public institutions and private investors is required. By spreading investment risks among multiple financiers, each with differing risk appetite and investment horizons, public or development finance can be used strategically to improve the risk-return profile of a project and to mobilize additional investment – like in the blended finance arrangements – thus "crowding in" private capital.

To reach a stage of maturity, the water sector needs strategic financing schemes such as blended finance. This sort of strategic finance can be provided by national and multilateral development banks, as well as some philanthropic investors. By involving private players, such as impact investors, project financing can be enhanced especially in developing countries and more remote areas, as these private investors usually operate following a specific investment mandate.

Increased private participation in financing generates multiple advantages, such as the possibility to implement procurement models as the BOT or BOO/BOOT which transfers part of risks to the private party and promote innovation and efficiency as these players seek an acceptable level of profitability while guaranteeing essential water services to the populations.

The case of OSMOSUN, operating in a niche market with few other players, indicates a way of contributing to Sustainable Development Goals which investors have to watch closely, as it merges the provision of drinking water services in rural communities with renewable energy production and strong attention to environmental impact.

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