Industrial desalination as a tool to solve water crises. The Saudi approach applied to the South African case

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Agenda

1. *The socio-economic effects of a water crisis in big urban agglomerations*
2. *Case study of Cape Town water crisis (2018)*
3. *Desalination as a tool to prevent water shortages*
4. *Saudi Arabia's desalination approach: advantages and disadvantages*
5. *Solar desalination: a solution for Sub-Saharan water shortages?*
6. *Solar desalination in Kenya and Namibia: innovation and progress*

Expected outcomes

1. Understanding the **economic impact** of a water crisis at the local and **national level**.

2. Comprehending the importance of **urban planning** to avoid water crises in large cities.

3. Understanding the **environmental impact** of **fossil-driven industrial desalination**.

4. Evaluating **sustainable alternatives** for desalinized water production through understanding the **solar energy market**.

5. Devising **new socio-economic development strategies** for **sub-Saharan Africa** through the exploitation of **solar energy**.

Teaching approaches to water crises in Large Urban Agglomerations (LUA)

Macro-general approach →	I intend to understand the complexity of water crises from a general standpoint applied to large urban agglomerations.
Micro-empirical approach →	I intend to examine a case study focusing on preventative methods.
Solution-based approach →	I intend to identify solutions that can solve and potentially prevent water crises in large cities. Analysis of solutions identified and applied in Africa.

Macro-general approach

Water and urban development

Currently, urban areas are being threatened by water shortage due to **climate change** and **rapid population growth**.

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The effects of urban development patterns on future municipal water shortage **need thorough investigation** to prevent water supply crises in large urban agglomerations.

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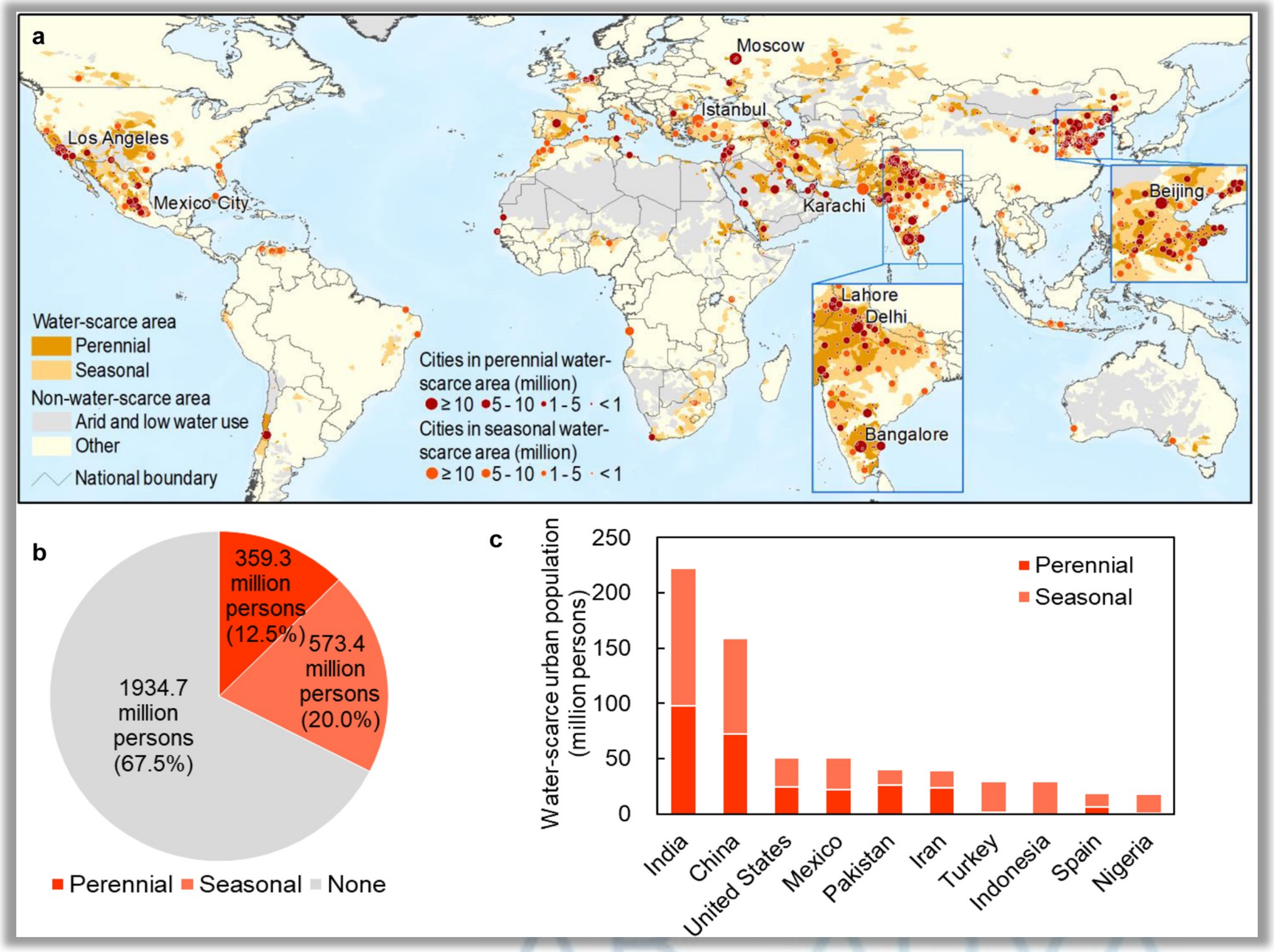
Today, **55%** of the global population lives in urban areas, a percentage that is expected to increase to **68%** by **2050**.



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Water crises and large urban agglomerations

In the event of a water crisis, **large urban agglomerations** are subjected to serious social and environmental hardships.

Water Crisis in Cape Town (2018)

Water Crisis in Chennai (2019)

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Projected population of LUA on a global scale (2010 – 2100)

LARGEST CITIES WITH EXTRAPOPULATIONS

2010		2025		2050		2075		2100	
City	Populations (millions)	City	Populations (millions)	City	Populations (millions)	City	Populations (millions)	City	Populations (millions)
TOKIO	36.094	TOKIO	36.400	MUMBAI	42.404	KINSHASHA	58.424	LAGOS	88.345
MEXICO	20.117	MUMBAI	26.385	DELHI	36.157	MUMBAI	57.862	KINSHASHA	83.494
MUMBAI	20.072	DELHI	22.498	DHAKA	35.193	LAGOS	57.195	DAR EL SALAAM	73.678
BEIJING	19.610	DHAKA	22.015	KINSHASHA	35.000	DELHI	49.338	MUMBAI	67.240
SAO PAOLO	19.582	SAO PAOLO	21.428	KOLKATA	33.042	DHAKA	46.219	DELHI	57.334
NEW YORK	19.441	MEXICO	21.009	LAGOS	32.630	KOLKATA	45.088	KHARTOUM	56.594
DELHI	17.015	NEW YORK	20.628	TOKIO	32.622	KARACHI	43.374	NIAMEY	56.149
SHANGHAI	15.789	KOLKATA	20.560	KARACHI	31.696	DAR EL SALAAM	37.485	DHAKA	54.250
KOLKATA	15.577	SHANGHAI	19.412	NEW YORK	24.769	CAIRO	32.999	KOLKATA	52.395
DHAKA	14.796	KARACHI	19.095	MEXICO	24.329	MANILA	32.749	KABUL	50.270
BUENOS AIRES	13.089	KINSHASHA	16.762	CAIRO	24.035	KABUL	32.672	KARACHI	49.056
KARACHI	13.052	LAGOS	15.796	MANILA	23.545	KHARTOUM	30.681	NAIROBI	46.661
LOS ANGELES	12.773	CAIRO	15.561	SAO PAOLO	22.825	TOKIO	28.916	LILONGWE	41.379
CAIRO	12.503	MANILA	14.808	SHANGHAI	21.317	NAIROBI	28.415	BLANTYRE CITY	40.911
RIO DE JANEIRO	12.171	BEIJING	14.545	LAHORE	17.449	NEW YORK	27.924	CAIRO	40.543
MANILA	11.662	BUENOS AIRES	13.768	KABUL	17.091	BAGDAD	24.388	KAMPALA	40.136

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Water and Mega Slums

Urban areas are expected to absorb all of the world's population growth in the coming decades, as well as accommodate rural-to-urban migration.

Floating slum in Lagos - 2020

Water and Urbanization

In the coming years, the majority of urbanites will live in **overcrowded**, **impoverished** and **unplanned** settlements with inadequate water and sanitation services. Reaching poorer communities will be vital to protecting **public health** as a whole, and to withstanding the impacts of climate change.

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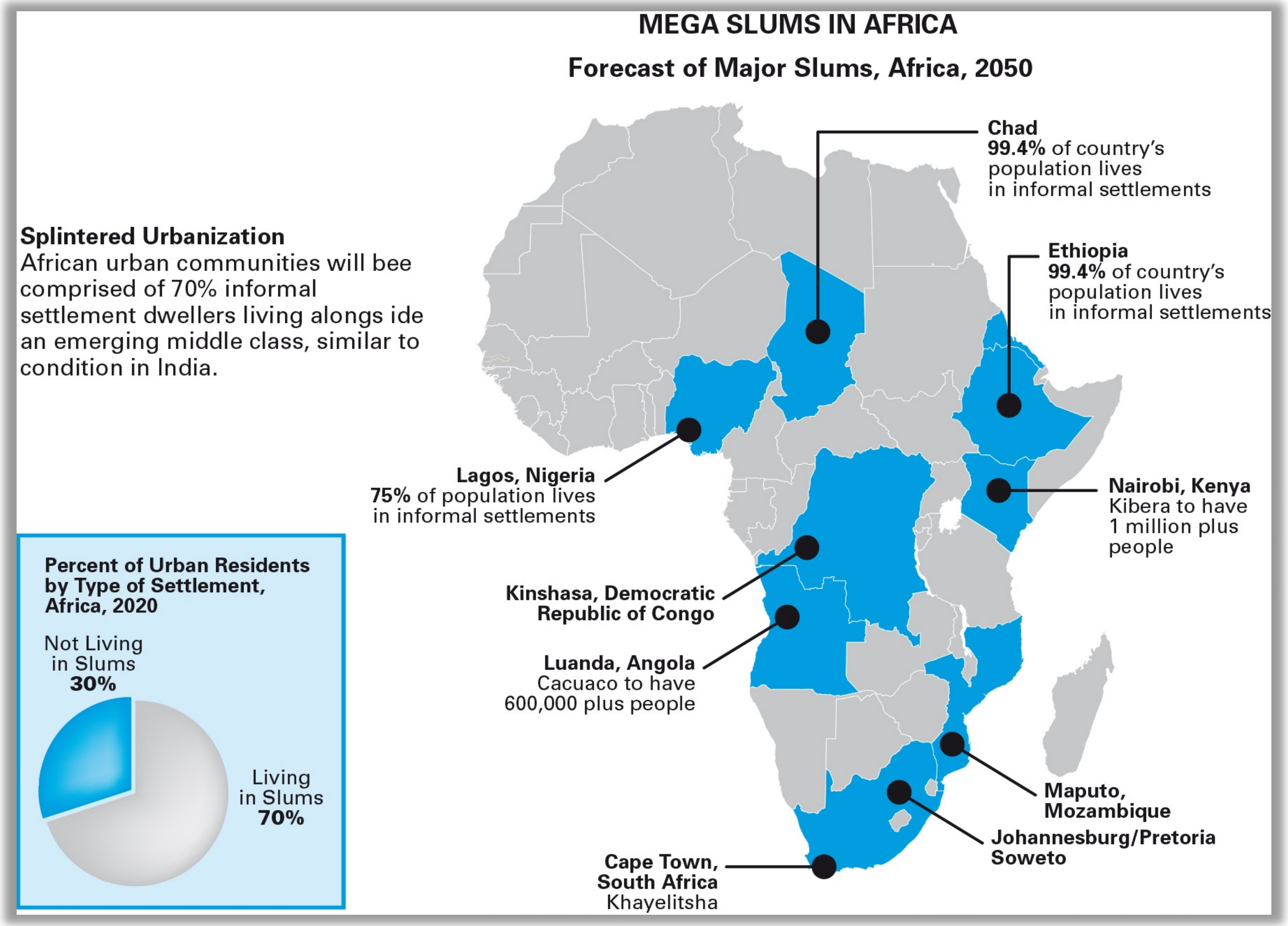
Large urban areas are vulnerable to **scarcity**. Fast growing towns and cities across the developing world are home to millions of people living without access to **basic services** such as safely managed water and sanitation services.

Mega Slums in Sub-Saharan Africa

Urban planning is not keeping pace with population growth. Inadequate planning, budgets and infrastructure are failing to serve most urban residents in the developing world with water and sanitation, contributing to **poor health conditions** and **heavy pollution** loads in wastewater.

Unplanned slum areas pose a wider **health risk**. Unsanitary conditions in neighbourhoods without water and sanitation services create a **constant threat of disease outbreak**, such as **cholera**, that can devastate poor communities and spread through the city and beyond.



Max urbanization and fertility rate

The UN has revised its projections on population growth and has “**cut**” as many as **100 million** from Nigeria’s population that was projected for 2060.

The UN also reduced Nigeria’s projected population by as much as 350 million at the end of the century.

In Nigeria, which is the most relevant demographic example in Africa, the average fertility **has** recently **dropped** from **6.5** children per woman to **5.2** children.

Max urbanization and fertility rate 2

Nigeria is by no means an isolated case, the trend is general: **Mali** has seen fertility of women drop from 6.3 to 5.2 children during the last decade, **Senegal** has “lost” a child for every woman in the same period, **Ghana** fell from 4.2 to 3.8.

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The African continent is rapidly becoming an **area of megacities**, marked by huge urban concentrations such as Lagos, Nairobi, Cairo, Johannesburg, Addis Ababa and many others.

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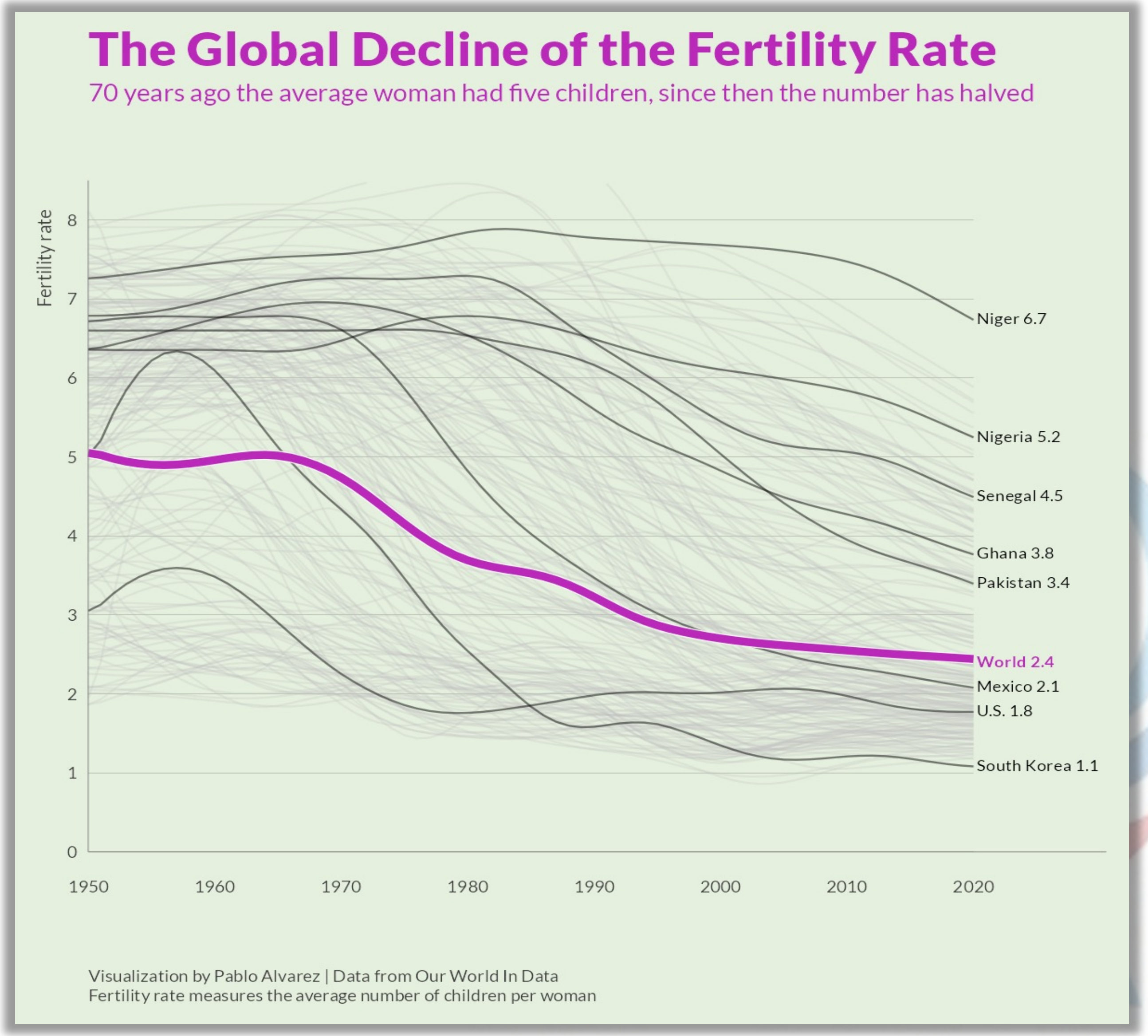
Women who move from the countryside to urban centres adopt very different customs and value models, especially **if compared to rural areas**.

Life in cities is more **dynamic**, **busy** where women often experience **less support from families of origin**. Therefore, among other things, African women who live in the cities tend to have fewer children.

The global decline of the fertility rate

Over the last 50 years, fertility rates have dropped drastically around the world. In 1952, the average global family had five children, now, they have less than three.

Main reasons: women's empowerment over the years, particularly in education and the workforce, as a consequence of urbanization.



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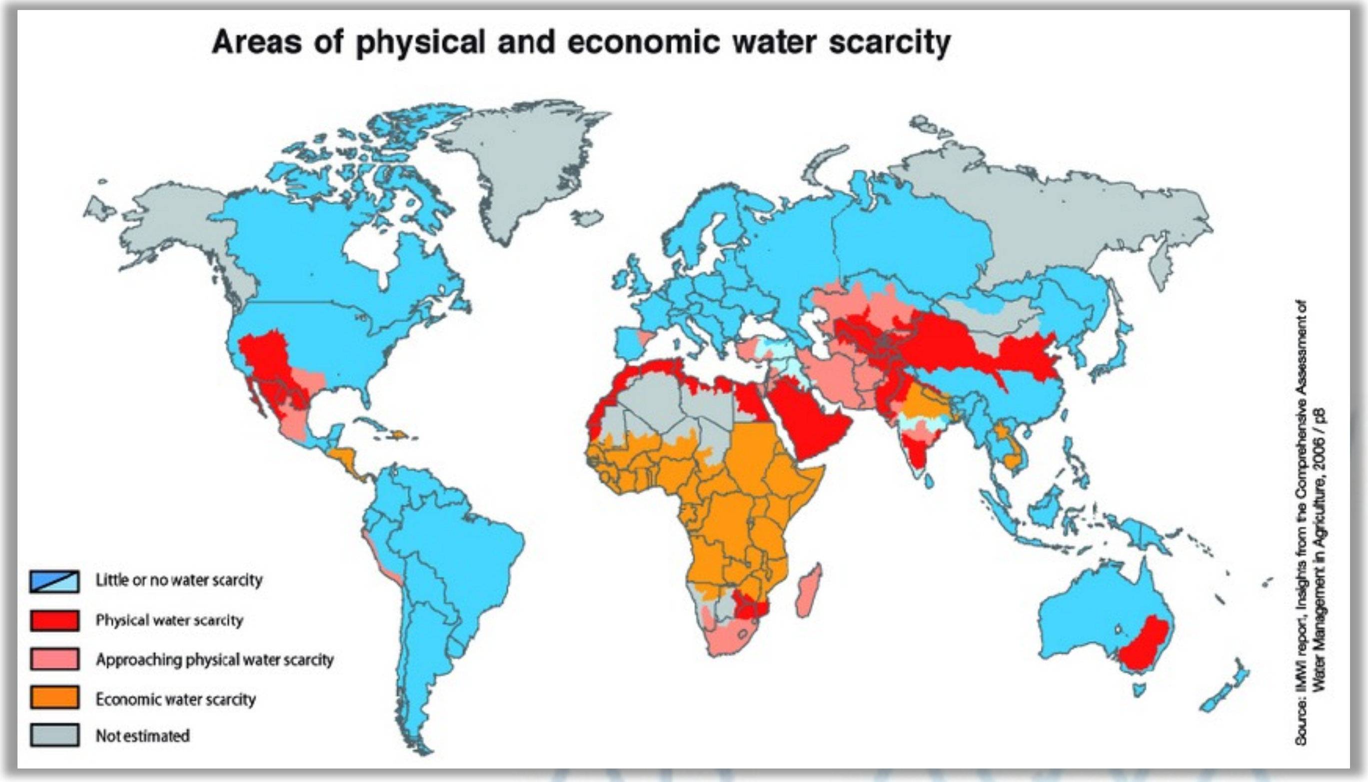
The economic effects of water shortages

Water is a finite resource in **growing demand**. As the global population increases and resource-intensive economic development continues, many countries' water resources and infrastructure are failing to meet accelerating demand.

Water scarcity is an **increasing problem** on every continent, with poorer communities most negatively affected.

In **rural** and **urban** Africa, poor and marginalized groups are on the frontline of any water scarcity crisis, impacting their ability to maintain good health, protect their families and earn a living.



Water and Job Opportunities

According to the U.N. World Water Development Report (2016), more than 1.4 billion jobs, accounting for 42% of the world's total workforce, are heavily dependent on water. It is also estimated that 1.2 billion jobs, equal to 36%, have an average level of dependence on water. Essentially, almost 80% (78%) of the global workforce depends on water.

From its collection, through various uses, to its ultimate return to the natural environment, water is a **key factor** in the development of **job opportunities** either directly related to its management (supply, infrastructure, wastewater treatment, etc.) or in economic sectors that are heavily water-dependent such as **agriculture**, **fishing**, **power**, **industry** and **health**.

In addition, good access to drinking water and sanitation promotes an educated and healthy workforce, which constitutes an essential factor for sustained economic growth.

Micro-empirical approach. Cape Town's water crisis

The importance of Cape Town in South African economy

Cape Town, located in Western Cape province, is one South Africa's main **economic centres** and Africa's third main economic hub city. It is also the second most important contributor to national employment (9,5% of the national workforce).

In 2019, the city's GMP (*Gross Metropolitan Product*) was **US$ 33.04 billion**, it represented **71.1%** of the Western Cape's total GRP (*Gross Regional Product*) and **9.6%** of South Africa's total GDP (*Gross Domestic Product*).

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The main causes of Cape Town's water crisis

Between February and April 2018, the economic capital, as well as the third largest city in South Africa, risked experiencing a nightmare situation: **total absence of water** both for production activities and for the primary needs of the population.

In those months, the situation was truly desperate: the "**Day Zero**", was set for April 22nd. An outbreak of **social disorder** and **tension** with dramatic scenarios was observed in the South African metropolis for several weeks. Essentially, the crisis was triggered by three factors:

- **Demographics**
- **Administrative conflicts**
- **Meteorological instability**

Cape Town's demographic growth

Cape Town is a large city of about **4M** inhabitants which has experienced massive demographic growth over the last few years. Since the mid-1990s, the population of this metropolis has increased exponentially.

In particular, since 1995, the city's population has grown by 79%. However, Cape Town's municipality and the South African government together have made modest changes to the water network, which in fact has been expanded by only 15%.

Cape Town's water facilities

Cape Town's water network consists of **six large dams** located in the mountainous area of the city. In theory, these water facilities should be able to meet the fresh water needs of its four million inhabitants.

The most relevant water infrastructure is the **Theewaterskloof dam**. Built in 1978 and inaugurated in 1980, it has a capacity of 480 million cubic meters of water, approximately 41% of the available water storage capacity in Cape Town.

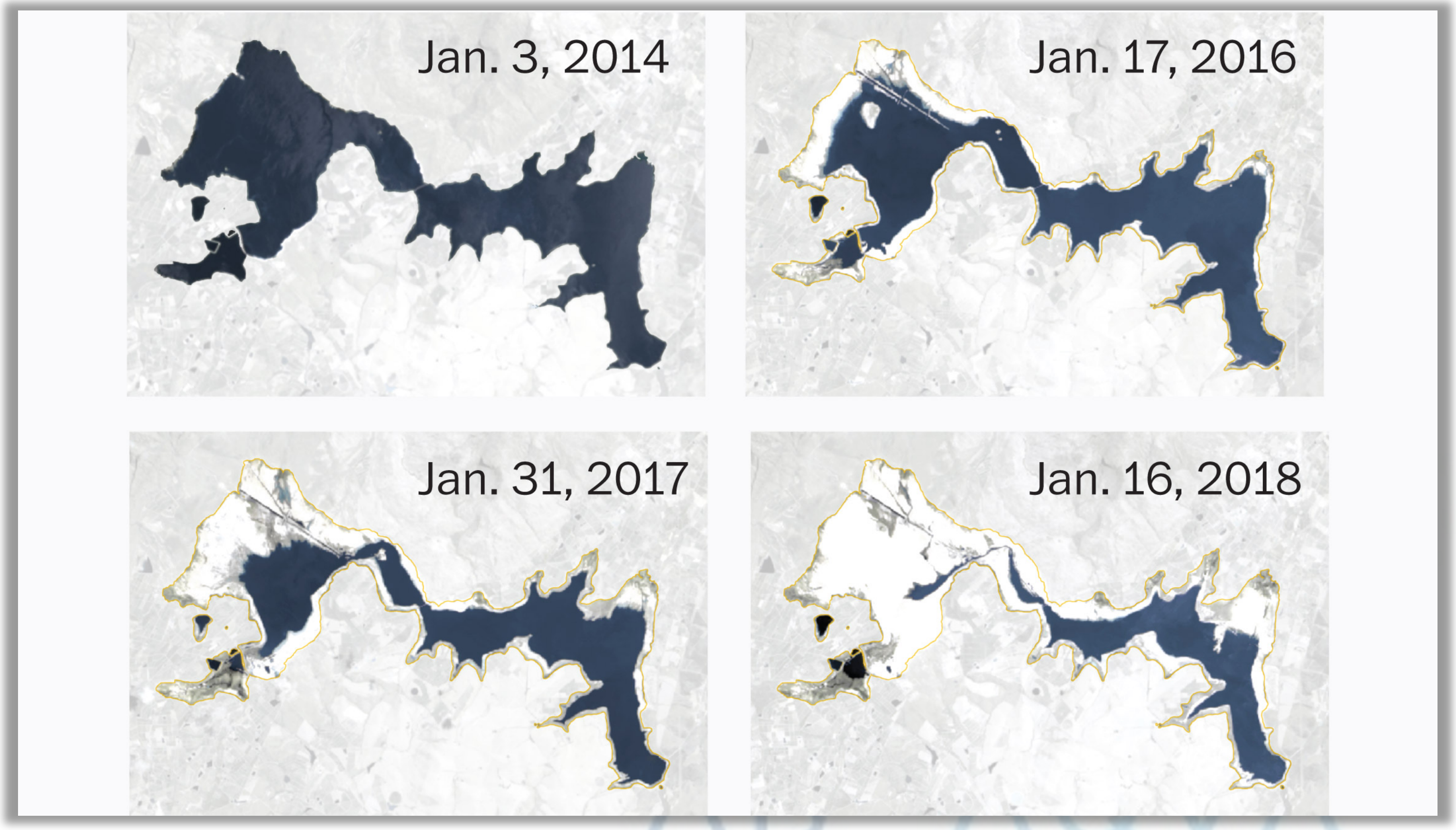
The Theewaterskloof dam

Cape Town's lack of rainfall in 2016 – 2018

A major role in the water crisis occurred in 2018 was played by the serious **lack of rainfall** which had affectd the whole province for about three years.

The years between 2016 and 2018 were the **driest in the country since 1933**, which is when precipitation started to be recorded in South Africa.

From 1,100 millimetres of annual rain in 2013, in 2017 rainfall had reached only 500 millimetres, i.e. less than half.



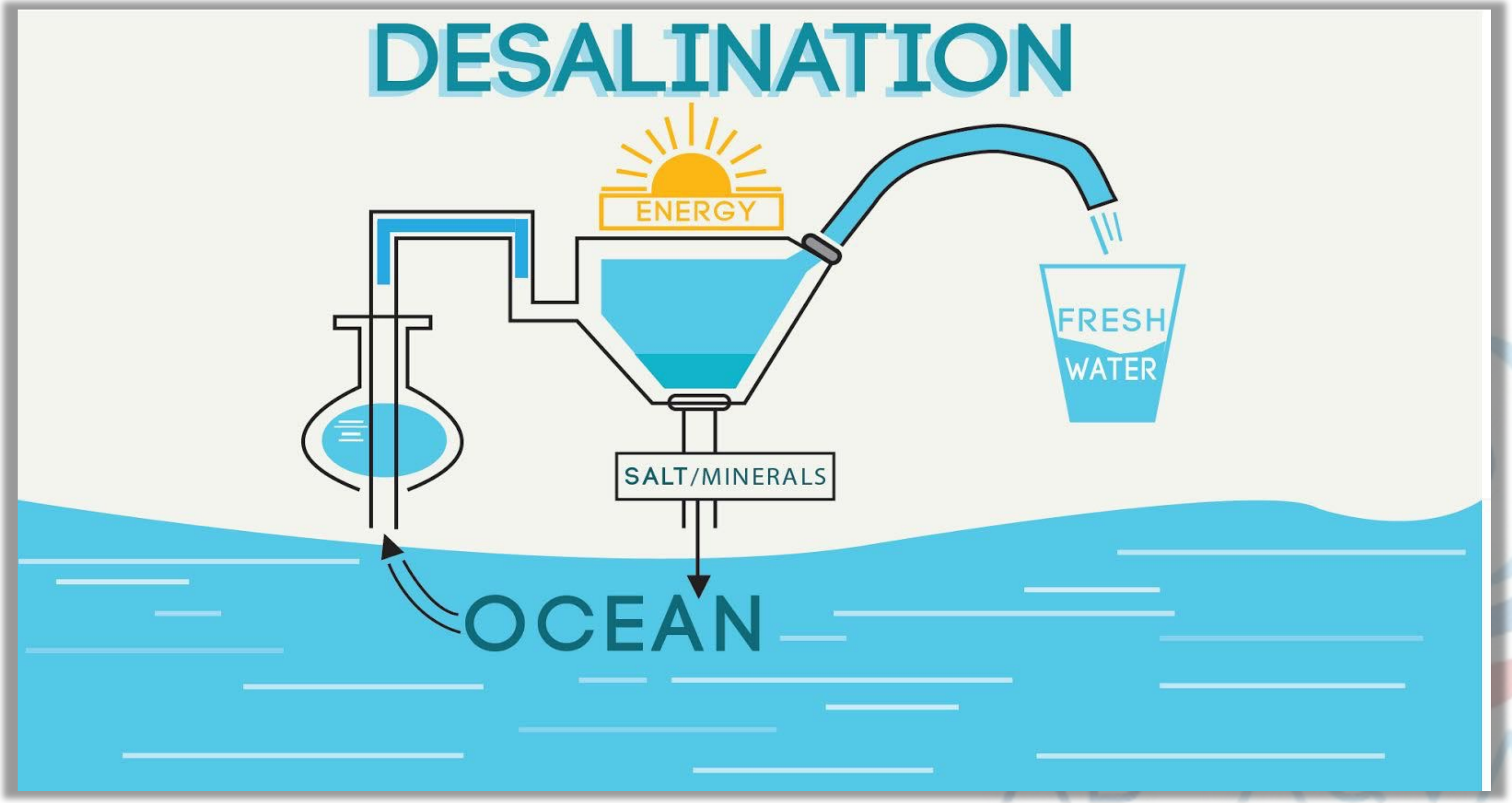
Administrative conflicts

According to South African law, it is the central state's duty to project, finance and build public infrastructures, while local administrations are responsible for ensuring that they function correctly and are properly used by citizens.

The delays in managing the water crisis was mainly caused by administrative conflicts. The **Democratic Alliance** (AD), a political organization in opposition to the governing party on the national level (**African National Congress**, ANC), has been administering the city since 2006 and the province since 2009.

Such **bureaucratic dichotomy** is not very functional for the effective management of the *res publica*, especially in times of crisis when decisions have to be taken with a certain speed.

Solution-based approach: desalination as a tool to prevent urban water crises



The Saudi approach: massive industrial desalination

Nowadays, Riyad has achieved **agricultural** and **food self-sufficiency**. In recent times, Saudi Arabia has become net exporter of agricultural products. The reason for such an astounding result is largely due to water policies that have been implemented over the last few decades.

A pillar of Saudi's water policy program has been the **large-scale use of desalination plants**. The abundance of sea water provides a constant supply to the Arabian Peninsula; surrounded by the sea in three large stretches, a wide availability of marine water resources is guaranteed.

The Saline Water Conversion Corporation (SWCC)

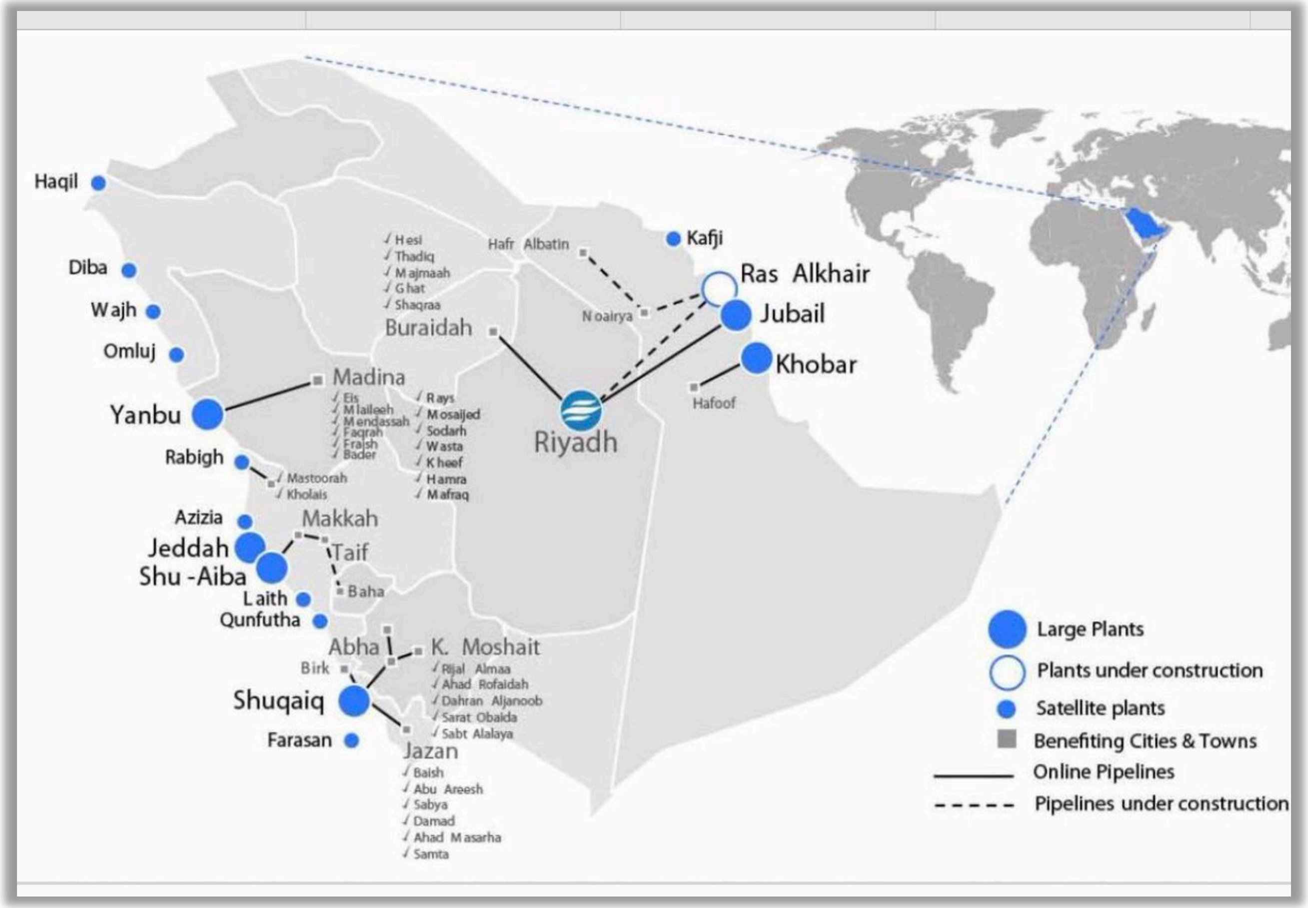
Founded in 1974, the **Saline Water Conversion Corporation** (SWCC) is the **largest seawater desalination company in the world**.

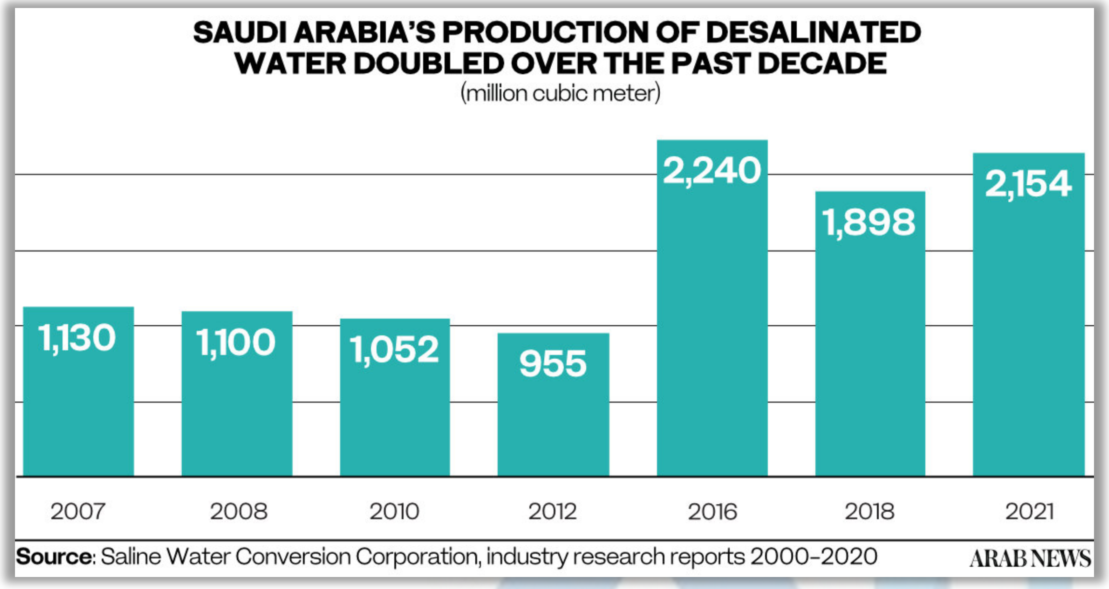
المؤسسة العامة لتحلية المياه المالحة
Saline Water Conversion Corporation

SWCC has approximately 30 large desalination plants operating nationwide, has over 4.000 km of water pipeline, employs approximately 10.000 Saudis. It is the second largest electricity provider in the Saudi Arabian Kingdom and has a commercial value exceeding 20 billion USD.

The plants managed by SWCC produce more than three billion cubic meters of drinking water a day and supply 70% of the water needs of all Saudi cities. Essentially, the Saline Water Conversion Corporation is a giant that has allowed Riyadh to ensure desalinated water to be used across diverse sectors.

The Saudi desalination production





The social impacts of Saudi's massive industrial desalination

Currently, wheat, milk and dairy products, meat and eggs are produced in the rural areas of the Saudi kingdom. This is a great achievement that has revolutionized the food production, diet and customs of the Saudi people.

Until a few decades ago, dates were the main product of the Saudi agricultural sector. This is largely due to the fact this fruit requires little water to grow.

Center Pivot Irrigation (CPI)

The abundance of water has allowed Saudi Arabia to change the food habits of its citizens, becoming a solid producer of agricultural goods.

Center Pivot Irrigation (CPI)

CPI in Pardoo Station - Western Australia

Center Pivot Irrigation is a method of crop irrigation in which equipment rotates around a pivot and crops are watered with sprinklers.

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A circular area cantered on the pivot is irrigated, often creating a circular pattern in crops when viewed from above (sometimes referred to as crop circles).

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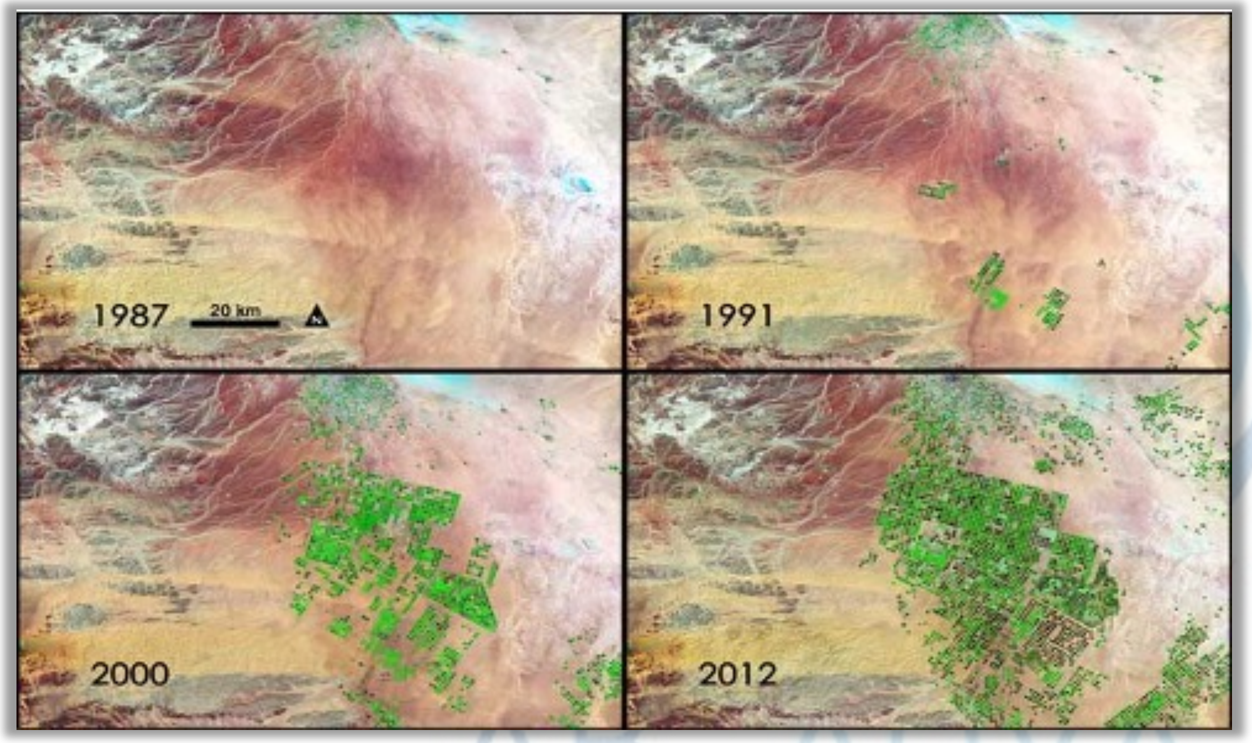
Center Pivot Irrigation systems are beneficial as they are water efficient and optimize farm yields. The systems are highly effective for use on large land fields.

Center Pivot Irrigation (CPI) 2

Center Pivot Irrigation was invented in 1940 by Frank Zybach, an American farmer who lived in Strasburg, Colorado. CPI is recognized worldwide as an effective method to improve water distribution to fields.

CPI fields photographed from the sky - Kansas



CPI's increase in Saudi Arabia (1987 - 2012)

Critical aspects of Saudi's desalination approach

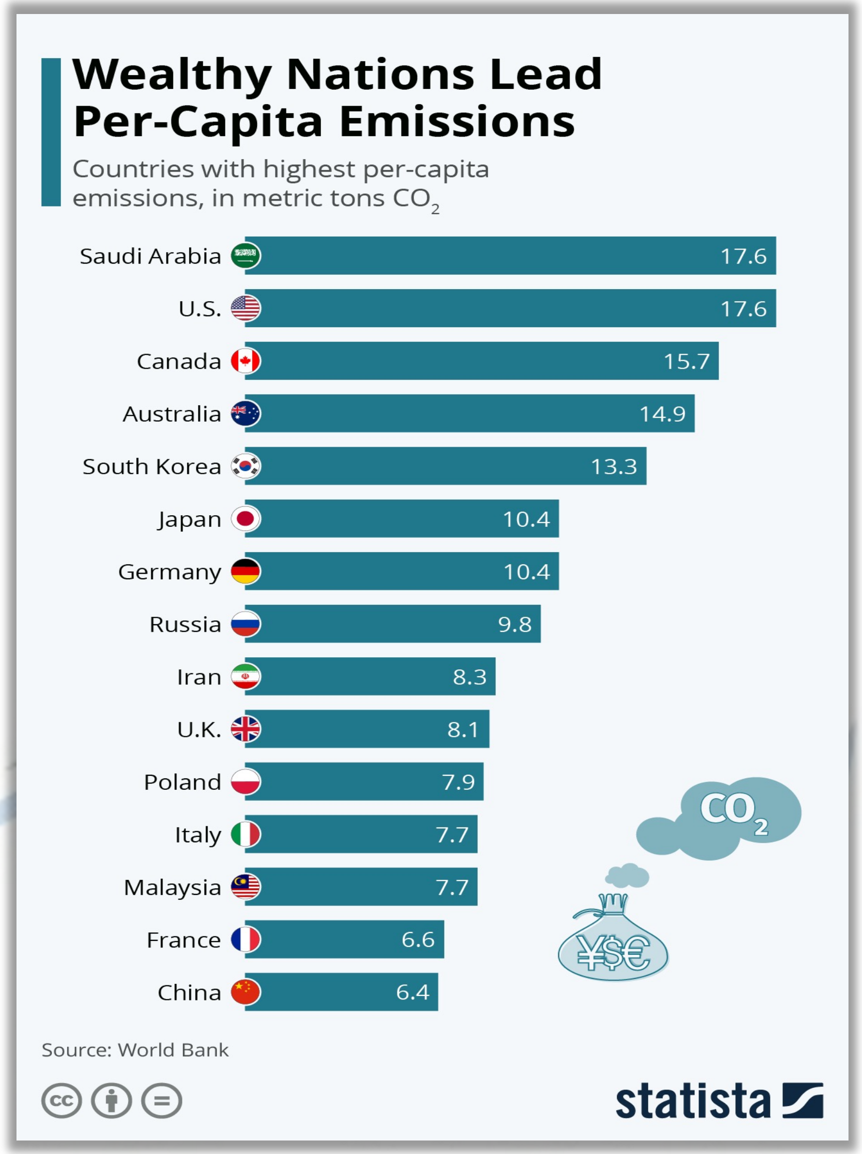
Can the Saudi approach which uses mass production of desalinated water be applied in other contexts?

The Saudi approach is very **expensive** and **polluting**.

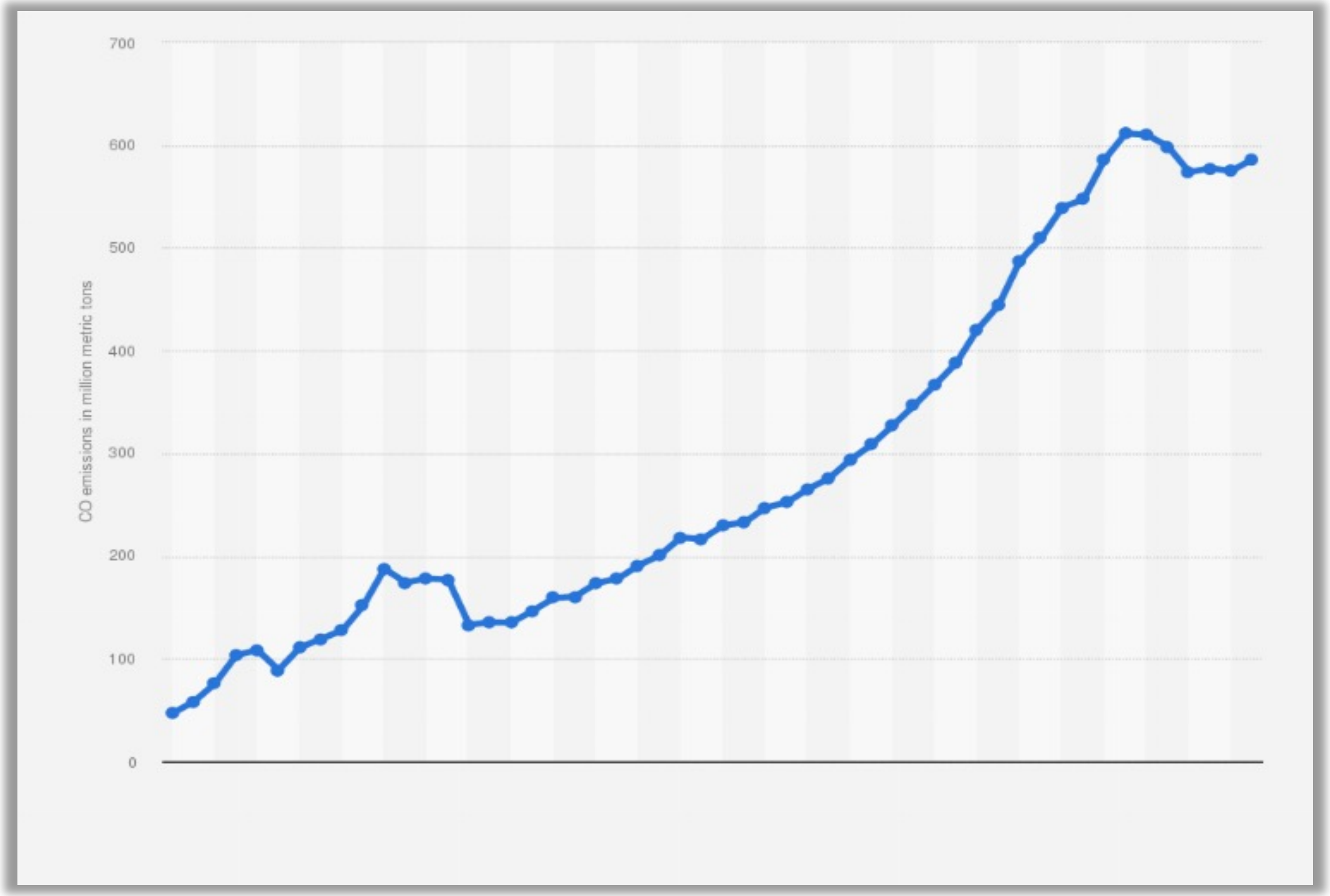
Saudi Arabia 's CO_2 emissions

To operate at the high pace imposed by Saudi policies, the SWCC plants use **high quantities of fossil energy,** which operate constantly over a 24hr period. In this regard, approximately **one third** of the oil extracted in the country is used in the production of desalinated water.

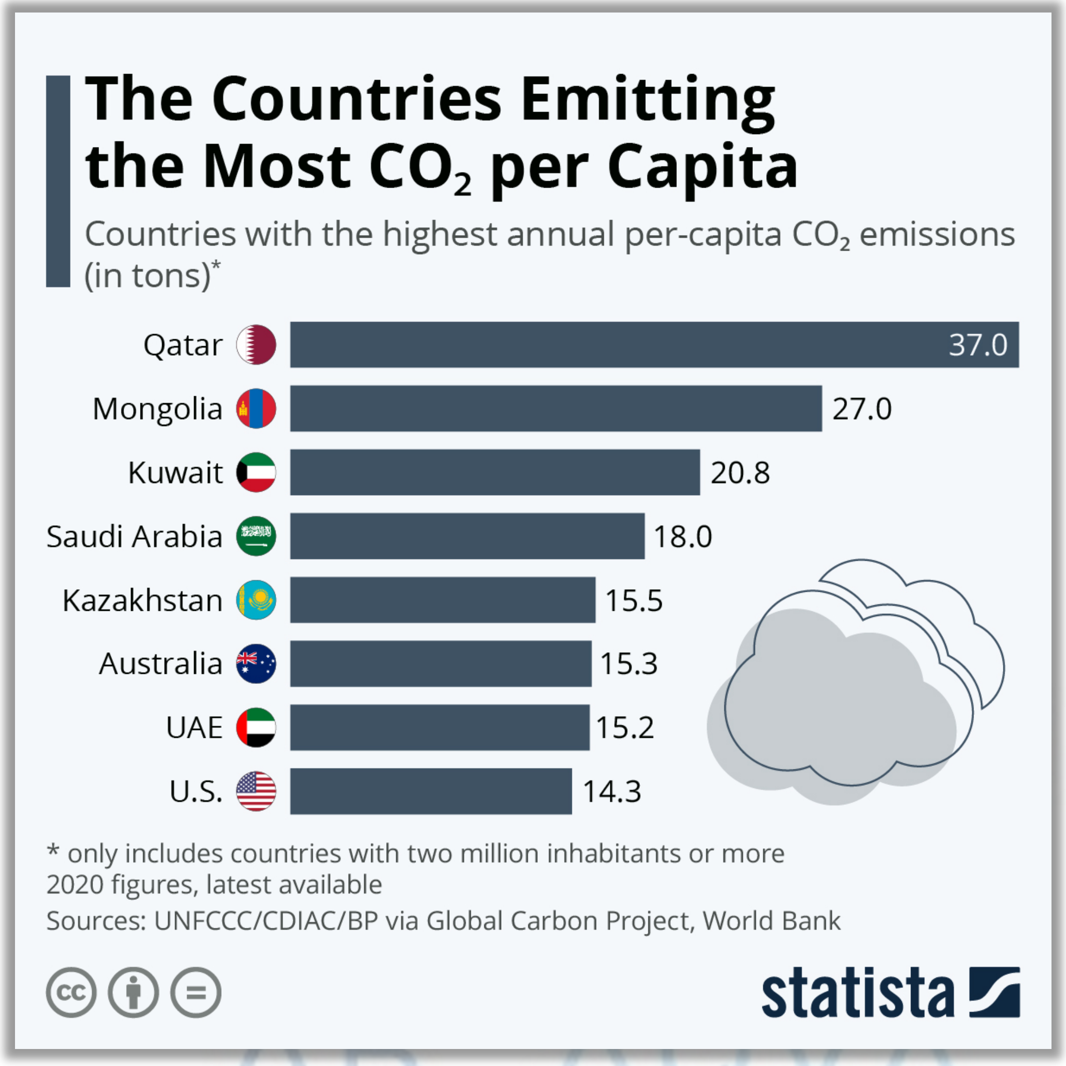
In 2016 alone, Saudi Arabia emitted more than **517 million tons** of **CO_2** into the atmosphere, confirming to be one of the largest contributors to carbon emissions globally. Desalination plants are largely responsible for these high emission rates.



Saudi Arabia 's CO_2 emissions



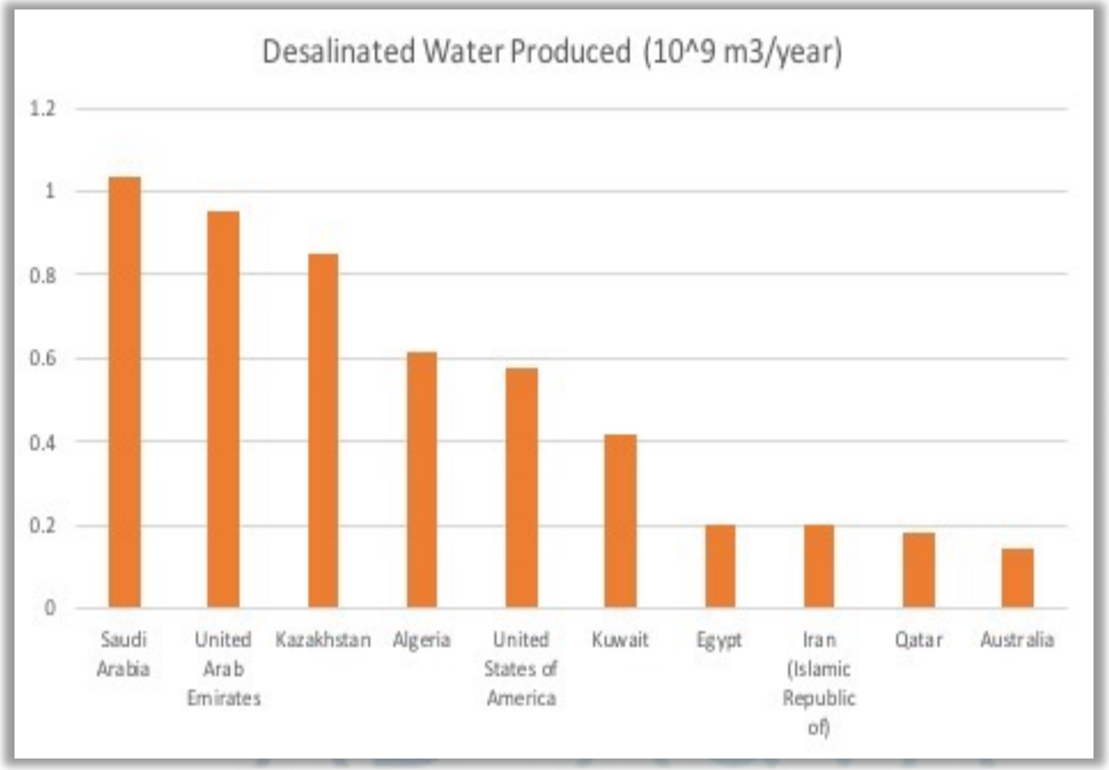
Saudi Arabian fossil fuel CO_2 emissions 1970-2021



Fossil fuels and traditional desalination

Desalination of seawater and brackish water is a very energy **intensive process.** Often using energy supply from **fossil fuel sources** which are vulnerable to volatile global market prices as well as logistical supply problems in remote and island communities and therefore are not sustainable.

Until recently, the majority of desalination plants have been located in regions with **high availability of fossil fuels** and low costs of energy.



Solar-powered desalination: innovation and progress

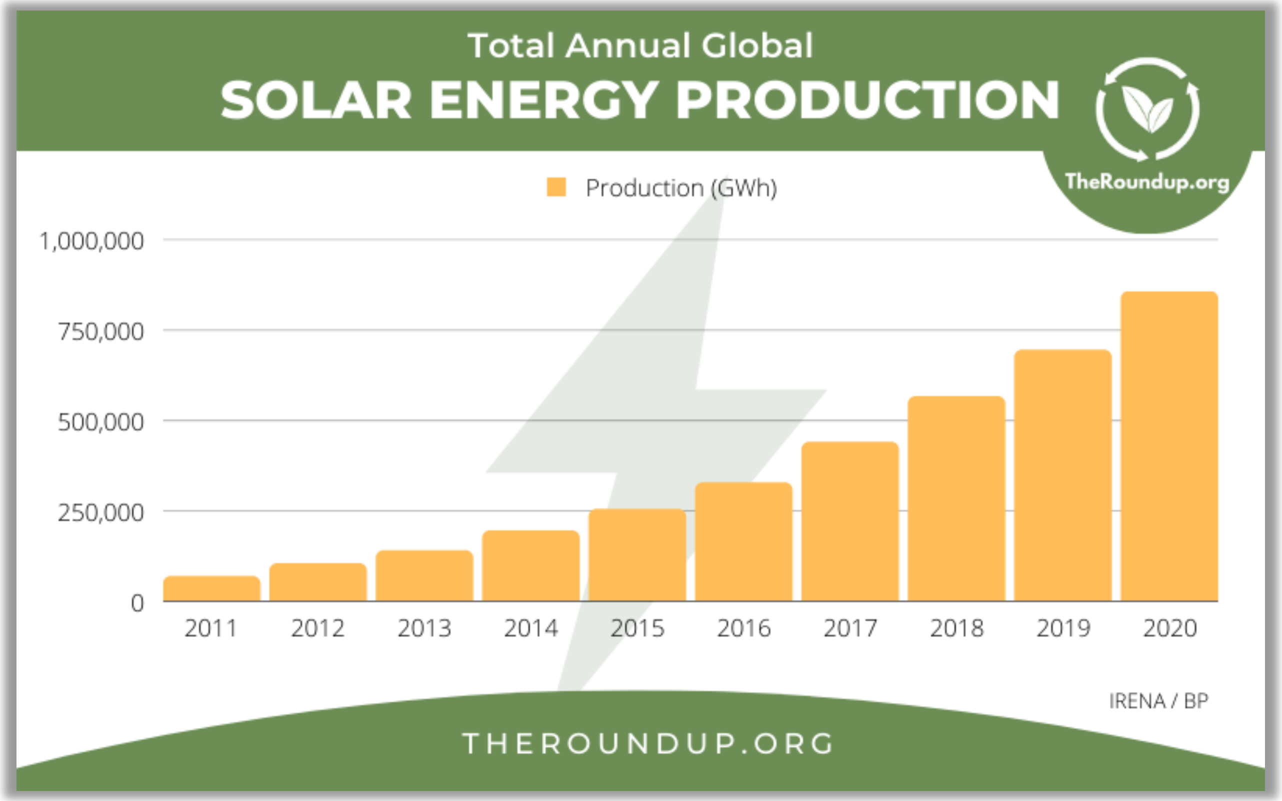
Until recently, the majority of desalination plants have been located in regions with **high availability of fossil** fuels and low costs of energy.

However, according to **International Renewable Energy Agency (IRENA)**, in the next few years renewables will play a relevant role in producing desalinated water.

Solar energy is the most promising renewable energy source for producing desalinated water due to its ability to drive the more popular thermal desalination systems directly through solar collectors and to drive physical and chemical desalination systems indirectly through photovoltaic cells.

Solar energy production

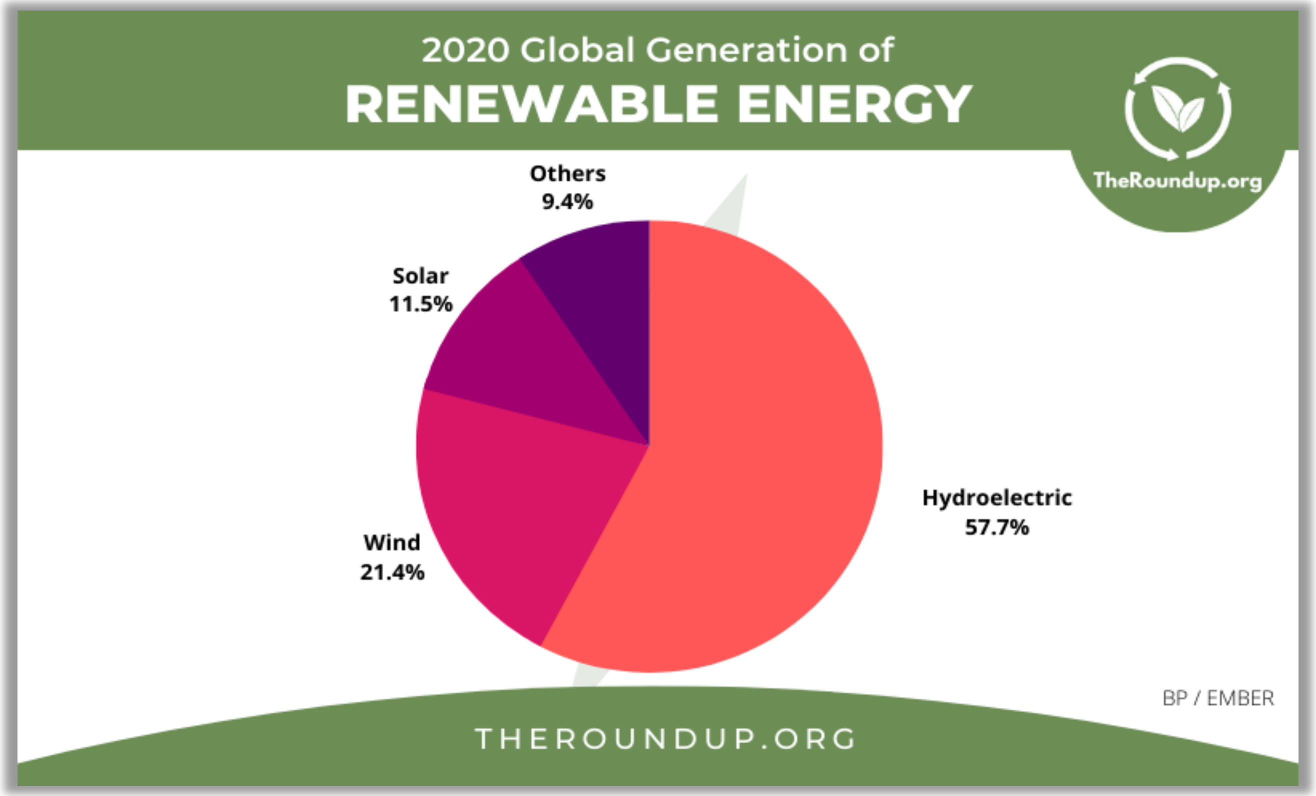
The world's current solar energy capacity is **850.2 GW** (GigaWatts). However, it is estimated that up to **173 000 TW** (TeraWatts) of solar energy can hit the Earth at any given moment. So we are still only using a tiny fraction of the energy available to us, which is far more than we are ever likely to need.



Renewables - and particularly solar energy - are becoming **increasingly mainstream** and technology prices continue to decline, thus making renewable energy a viable option.

Relevance of solar power in the renewable energy sector

While the largest renewable source is currently hydroelectric (57.7%) followed by wind (21.4%), solar capacity is **expanding at a much faster rate** than any other renewable energy source.



The constant increase in electricity production through the exploitation of solar energy will represent the **most relevant challenge** for future generations for a productive and sustainable approach.

Solar water desalination market

With increasing demand for desalinated water in energy-importing countries such as India, China and small islands, there is a **large market potential** for renewable energy-powered desalination systems worldwide.

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While desalination is still costly, declining renewable energy technology deployment costs are expected to bring this **cost down** in the coming years.

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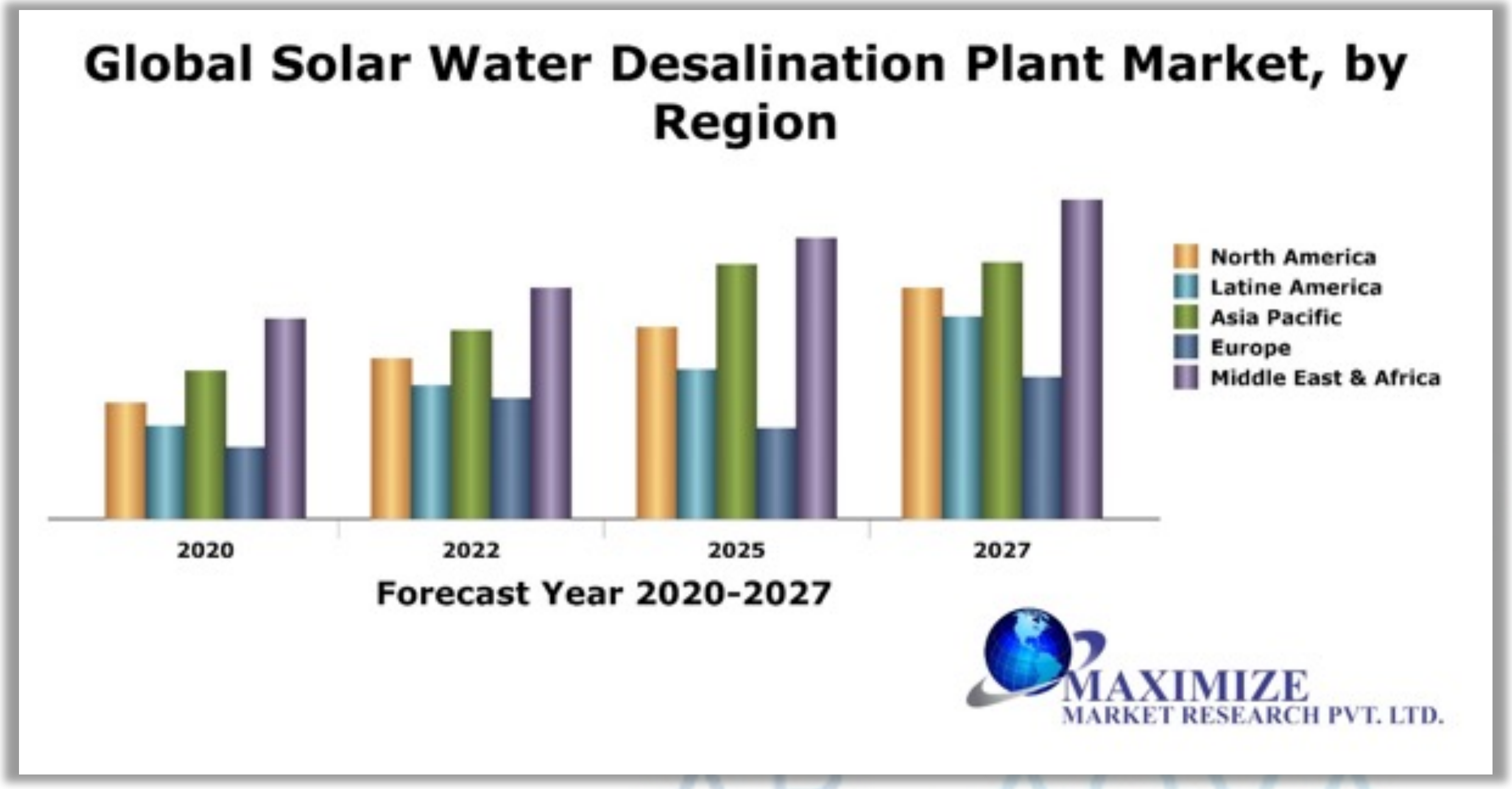
This is of particular interest to remote regions and islands with small populations and poor infrastructure for freshwater and electricity transmission and distribution.



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Africa's solar power potential

According to the **International Energy Agency** (IEA), Africa has **60%** of the world's best solar potential, but only **1%** of solar generation capacity.

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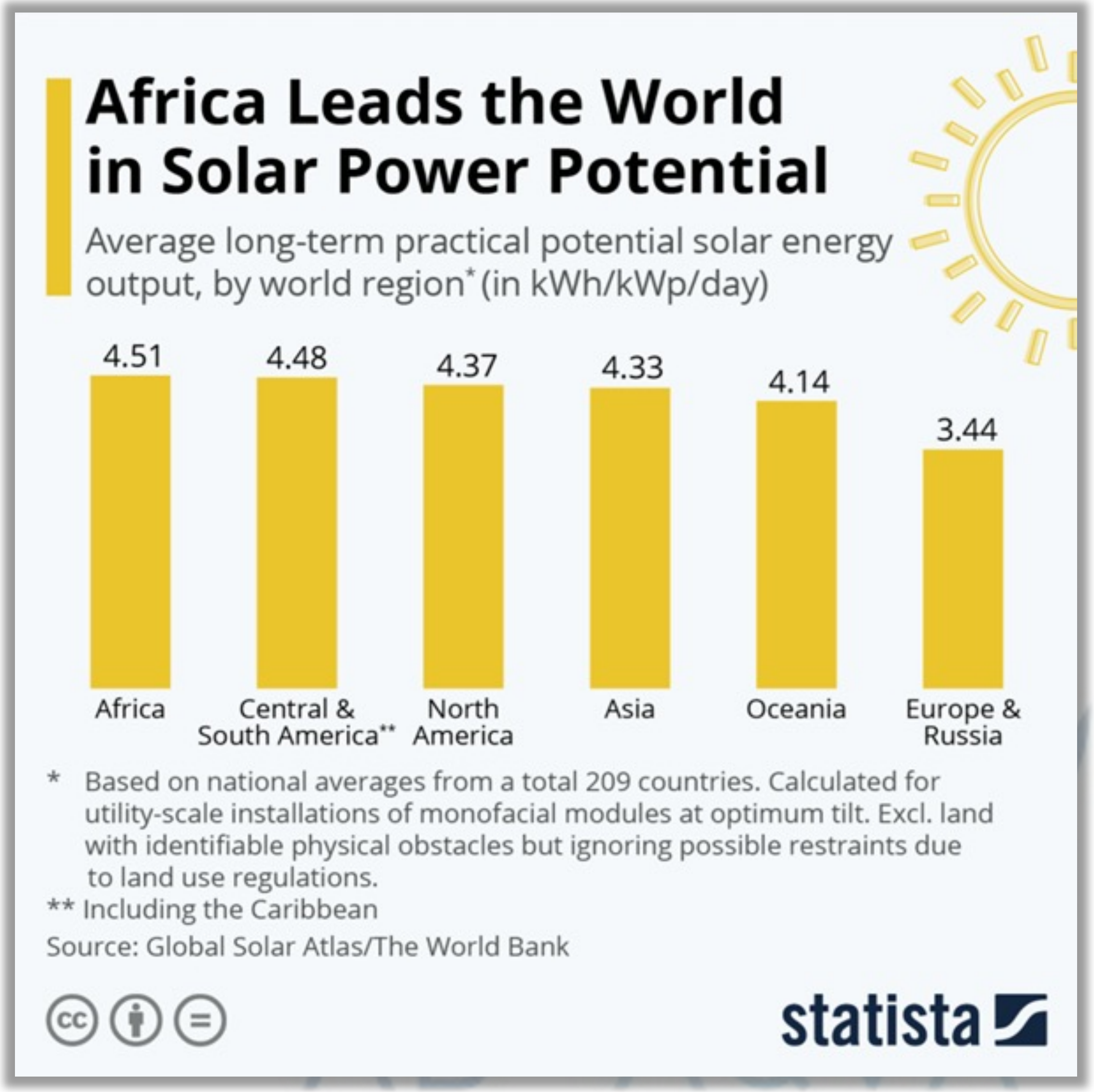
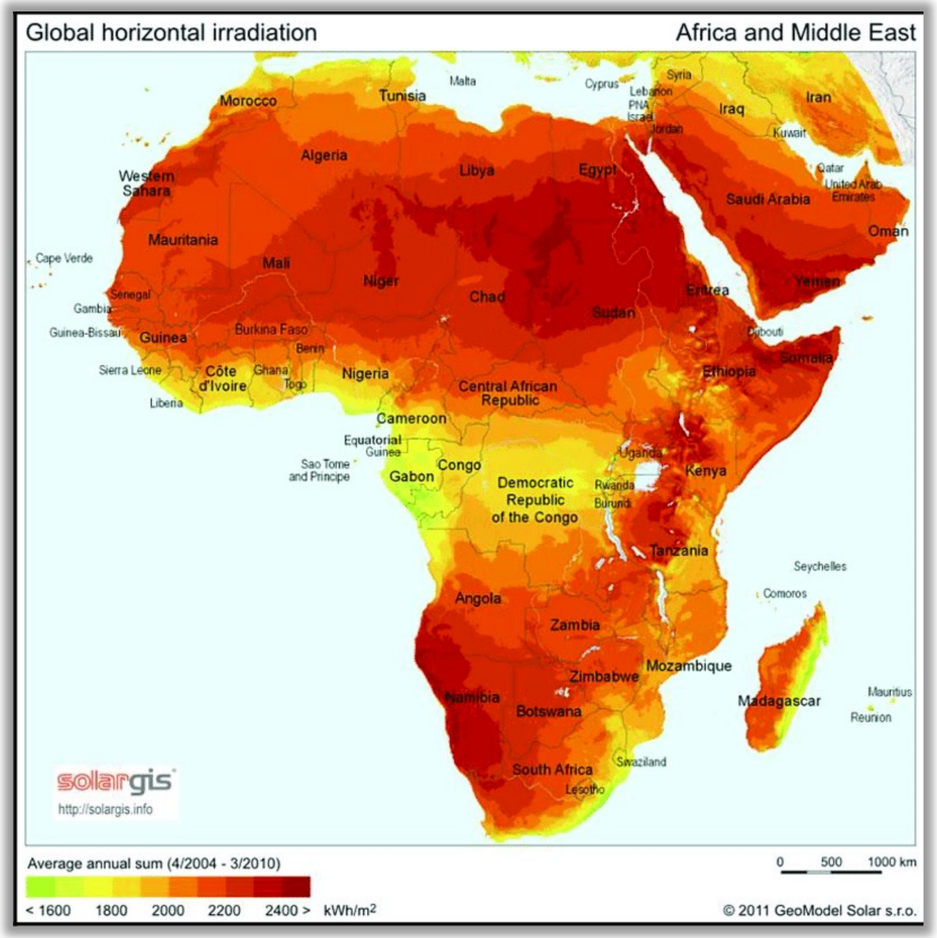
To achieve its energy and climate goals, Africa needs to invest **$190 billion a year** between 2026 to 2030, with two-thirds of this going to clean energy.



International investment in Africa's solar power potential

Recently, there has been a **growing attention** in building public-private partnerships and in engaging in international platforms focused on developing African solar power production.

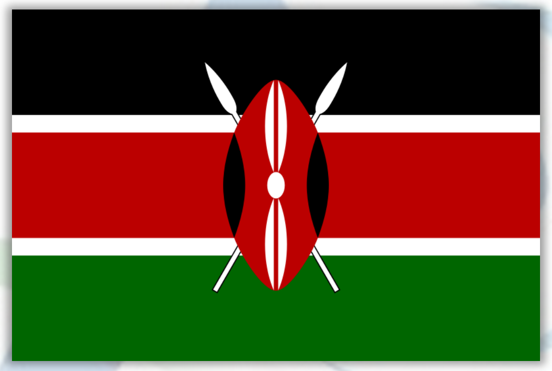


Concretely, the **World Bank**, the **African Development Bank**, the **European Union** and the **European Investment Bank** pledged to invest in supporting the development of African renewable energy.

The goal is to provide instruments such as **technical assistance**, **capacity building** and **financial support programmes** for specific projects aimed in particular at boosting the production of electricity through photovoltaic panels.

Solar desalination plant in Kiunga, rural Kenya

In Kiunga, a village in Kenya near the border with Somalia, a new solar-powered water desalination plant is providing 35 000 litres of fresh water per day. The plant serves over 25 000 residents in rural Kenya.



Kiunga's desalination power plant: efficiency and costs

According to ***GivePower***, the international energy foundation responsible for the project and construction of the water facility, the Kiunga solar desalination plant initially cost $500 000 to build and took only one month to construct.

Solar desalination plant in Namibia

Namibia's first-ever fully solar-powered desalination system has been commissioned as a joint initiative of the **University of Namibia** and the **University of Turku** in Finland.

The system is designed and delivered by a Finnish water technology company called ***Solar Water Solutions Ltd***.

The facility is among the first desalination systems in the world to operate on **100% renewable energy**.

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Solar desalination plant in Namibia 2

According to *Solar Water Solutions Ltd.*, the new plant produces safe water for **drinking** and **irrigation** purposes.

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The decentralized system, which is situated close to the beach and installed in a container, produces 3 500 litres of water per hour from the ocean with zero energy costs and without any batteries.

Arid conditions of Namibia

Namibia stands out as one the **driest countries in Sub-Saharan Africa** and one of those hardest hit by the effects of climate change.

The geographical conformation of the Namibian coast is particularly suitable for projects focused on **solar-powered desalination**.

The Namib is a coastal desert that stretches for more than 2 000 kilometres (1,200 mi) along the Atlantic coasts of **Angola**, **Namibia**, and **South Africa**.

Advantages of solar powered desalination

1) Containment of plant construction costs

According to ***Solar Water Solutions Ltd***, life-cycle costs of the Namibian solar-powered desalination solution are more than 70% lower than conventional systems.

2) Environmental sustainability

According to both ***Solar Water Solutions Ltd*** and ***GivePower***, solar desalination plants have zero emissions and zero carbon footprint.

3) Increasing investments from international banking institutions

The environmental sustainability of this desalination method will become **increasingly popular** in the coming years, driven by the reduced costs and the respect for the environment.

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