The end of natural water scarcity

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Abstract

It has been widely proposed that water scarcity is unavoidable and may or not lead to conflicts. Most authors jump directly to the consequences of a supposed idea of water scarcity. Here, we reject this hypothesis through two arguments. Firstly, we remind that fresh water stocks are fed by oceans, hence, it is incongruous think about water scarcity. Secondly, we demonstrate that presently, humankind is able to produce freshwater in industrial rhythm, leading to a total independence of groundwater. Using a 12-year dataset of water production in Dubai, we show that production of freshwater from desalination plants and from groundwater sources grows inversely indicating that this latter is irrelevant to water supply and its contribution will soon be annulled. We then conclude that water must be conceived not only as 'inexhaustible', but also as a 'producible' resource.

Keywords

Water, scarcity, desalination, inexhaustible

I Background and introduction

The threat of water scarcity has been widely emphasised by scientists, politicians and the mass media. For many years, most scientific articles on this subject have suggested that water scarcity will cause conflicts in the future. This idea is known as the 'water-war hypothesis'. Gleick (1993), Homer-Dixon (1999), Ohlsson (1999) and Berman & Wihbey (1999) have all stressed this possibility. The last authors, referring to the Middle-East, claimed that nations would be sliding toward conflict over water. In addition to academic experts, political authorities, including three UN Secretaries-Generals, have strongly warned of conflicts due to water scarcity. According to Katz (2011) Boutros Boutros-Ghali, the UN Secretary-General from 1992 until 1996, asserted that "*The next war in the Middle East will be over water*". His successor, Kofi Annan, who was Secretary-General from 1997 until 2006, echoed this assertion in 2001: *"Fierce competition for freshwater may well become a source of conflict and wars in the future"*. The current UN Secretary-General, Ban Ki-Moon, has also emphasised that *"Water scarcity has created a high risk of violent conflict"*.

However, other scholars have disagreed with the water-war hypothesis; they argue that this prediction has been artificially created in response to various interests and that the prediction has no empirical foundation. These authors include Klare (2001), Simon (1980), Singer (1987), Rebouças (2004) and Katz (2011), who argue adamantly against the hypothesis. Based on the lack of empirical evidence for wars over water, Katz (op cit) severely criticises the proponents of the water-war hypothesis:

> *"By tying their primary cause to conflict over water, actors increase their visibility and offer those who sympathize with their mission an additional reason to offer support or take action. [...] Increasing the severity of their messages is one tactic to attract attention [...]. Doing so increases the potential to gain access to policy-makers and the media [... and] also expands possibilities for further research collaboration."*

Nevertheless, within the context of this discussion about whether water scarcity will cause conflicts, studies questioning water scarcity itself are lacking. Water scarcity appears to have been universally accepted among scientists and politicians as a Malthusian paradigm in which technical developments are not adequately considered. Because the inevitability of water scarcity is universally believed, most writers skip directly to its consequences and barely address the issue of scarcity itself. The present article aims to fill this gap by demonstrating that natural water scarcity will soon no longer be a problem.

First, we demonstrate that it is not reasonable to consider water scarcity on a global scale because this resource is one of the most abundant on Earth and because the hydrological cycle will persist as long as natural forces, such as gravity, solar energy and the rotation of the earth, remain in effect. Thus, we can reasonably consider water scarcity only on regional or local scales. We then distinguish natural and social water scarcity and make evident that in many regions, the lack of access to water is due to mismanagement rather than natural scarcity.

Given these premises, we then selected a regional context to provide an empirical example to the analysis of a decreasing dependence on natural groundwater sources. We analysed a 12-year water-production dataset from emirate of Dubai comparing water production with demand, and quantifying the proportion of the total water production that is derived from ground sources and the proportion that is derived from desalination. The results made evident that in Dubai, increasing use of desalination technology is leading toward complete independence from groundwater sources, which would definitively end natural water scarcity. The same trend is occurring in other countries of the Arabian Peninsula, such as Saudi Arabia, Bahrain, Kuwait and Qatar. However, we focused on Dubai because our aim is simply to demonstrate that water scarcity is ending in some regions, and we did not intend to quantify the extent to which this process is occurring. We also showed that energy costs and demand have decreased considerably in the past decade, thereby indicating that desalination could soon be widely employed in densely populated arid regions throughout the world. New technologies have reduced the amount of petroleum and gas required, and new materials and techniques have been incorporated into the desalination process; both types of changes have made the desalination process more efficient and less expensive.

Assuming that desalinated water can be produced at a large scale, we conclude by proposing a conceptual adjustment: rather than merely a renewable natural resource, water should be considered a producible resource similar to those produced through agriculture and mining.

II Theoretical development of the general framework

1 *A water planet with some dry regions*

Any discussion of water must consider the global scale, including the oceans. Although ocean water is not immediately available for human consumption, it represents the greatest natural source of water, and it will indefinitely replenish continental freshwater stocks through natural hydrological processes, such as evaporation and precipitation. Worldwide, the land surface receives approximately 40,865 cubic kilometres of meteoric water (primarily rain, sleet and snow) each year (Camp, 2009, p. 162). Mauser shows figures much higher: 110km3 of precipitation per year just over continents (2009, p.7).

In contrast, if we adopt a fragmentary approach that considers only continental freshwater, we must assume that all rivers 'die' when they reach the ocean. Thus, the Amazon River alone 'destroys' more than 200,000 cubic metres of freshwater per second at its mouth. Therefore, it is incongruous to treat freshwater and saltwater separately. Given this, it is unreasonable to consider global water scarcity because water is the one of the most abundant natural resource on our planet by far. Because the quantity of water that exists on Earth (approximately 1.4 billion cubic kilometres, according to Camp, 2009, p.160) is so much greater than the amount that is used by humankind, water can be considered an inexhaustible natural resource. It is unthinkable that global water stocks could be dangerously reduced, much less depleted. Furthermore, an immense quantity of freshwater is stored at the poles (23.8 million km^3, or 68.9% of all freshwater on Earth). Even when one considers only the meteoric water that comes from the atmosphere, the global depletion of water stocks is highly improbable, given the quantities cited above. Camp (2009, p.162) has asserted that *"[…] of that amount, about 588 cubic miles* [approximately 2,451 cubic kilometres] *of meteoric water falls in the United States each year [...]. We use about 19 percent of our potential water supply and almost 81 percent continues in the hydrologic cycle"*. Virtually all water that is withdrawn from the hydrological cycle by human activities will eventually return. Consequently, "*almost any use is temporary, so 'borrowed' might be a more accurate description of what happens to water"*.

Although the quantity of freshwater exceeds human needs on a global scale, many regions of the Earth's surface exhibit natural water scarcity. Regionally, water scarcity is caused by complex natural processes, especially climatic variables, such as low precipitation. But would people facing scarcity be a natural matter?

2 *Scarcity of planning and management*

We can easily identify regions or localities where natural water scarcity may cause severe challenges for human inhabitants. Such regions include northeast Brazil, northern Africa, the Arabian Peninsula and the southwest coast of the United States. Whether people are affected by water scarcity and live under harsh conditions is thus primarily a social matter rather than a natural one, and it has historical, political and management dimensions.

The historical dimension refers to the decision to settle in a given arid region that was made at some time in the past. Nature or climate cannot be blamed for the water scarcity that people face, although such mistaken blame is often exhibited in the media and among local government officials.

The political dimension is exemplified by northeast Brazil. Water scarcity can be generated or made worse by political inequality, such as when local politicians assure powerful farmers that they will have first access to the scarce water supply, thereby making poor people vulnerable to political bargaining.

The management dimension is perhaps the most important for explaining water scarcity because there is no other reasonable explanation for the high frequency of water-borne diseases in children in highly humid regions such as the Amazon River basin. Similarly, there is no other reason for periodic water rationing in highly humid and economically prosperous areas, such as the São Paulo and Curitiba metropolitan regions in Brazil. Rebouças (2003) has explained these contradictions in his article *"O Paradoxo Brasileiro"* (The Brazilian Paradox). He argues that these problems are due to mismanagement, which results in inadequate water treatment and distribution (in the Amazon) or overexploitation and inefficiency combined with leakage and fraud (in São Paulo and Curitiba). According to official data from SABESP (2012), the Sanitation Company of São Paulo State, 25.7% of all water produced in 2012 was lost through either leakage (65% of losses) or clandestine appropriation and fraud (35% of losses). Despite the inefficiency that these figures indicate, the average water loss in Brazil is even greater: according to official data from SNIS (2010), the National Sanitation Information System, approximately 35.9% of all treated water was lost in 2010.

At the opposite extreme, how can we explain the satisfactory water supply enjoyed by human populations in some highly arid regions, such as the Arabian Peninsula? Again, management is the primary explanation: in this case, effective management prioritises water production and distribution projects. In this region, water has been scarce since the beginning of human settlement. Therefore, effective water management has historically been a high priority, and ancient and modern systems coexist in some areas. In the Sultanate of Oman, for example, modern desalination plants, such as that in Sur, can produce 80,000 m^3/day (for a medium-size plant) to supply urban areas (Sur Desalination Plant, 2012), whereas 4,112 *aflaj*, an ancient system of canals that are partly covered to avoid evaporation, deliver water from the highlands to rural areas in the plains by means of gravity (Ministry of Information, 2010, p.221). Furthermore, numerous wells are spread across Oman and throughout the MENA region (Middle East and North Africa). Therefore, an adequate water supply requires not only solid financial support but also adaptability to natural conditions.

As a partial conclusion, natural water scarcity does not exist on a global scale, and water scarcity is a social rather than a natural phenomenon on regional and local scales. Therefore, solutions will always depend on political decisions that promote more efficient water management, including the planning of human settlements. In other words, water reserves are fixed, whereas humankind is flexible and capable of decision-making. Thus, humans bear the sole responsibility for whether they are affected by water scarcity.

III The Study Case and Methods

1 *Arabian Peninsula – the ocean leakage*

The Arabian Peninsula is one of the driest regions on Earth. Some countries there (e.g., Saudi Arabia, Yemen and Oman) have less than 500 m^3 of water per inhabitant per year, and others (e.g., UAE, Qatar, Bahrain and Kuwait) must rely on less than 100 m^3 per inhabitant per year (Smith, 2008, p.132-133). Nevertheless, these countries have proved that natural water scarcity need not be an obstacle to development but rather can be overcome through investment and technology. Today, some of these countries have nearly achieved total independence from groundwater sources and weather patterns.

Here, we focus on the emirate of Dubai, which is one of the seven emirates within the United Arab Emirates. Over a 12-year period, this emirate has exhibited significantly increasing water demand and production and decreasing groundwater use, as illustrated in figure 1.

Figure 1. Water production in Dubai, 2001 through 2012. Data obtained from http://www.dewa.gov.ae/aboutus/waterStats2011.aspx.

According to DEWA (2013), the Dubai Electricity and Water Administration, water production doubled over this period (increasing by 101,5%) and reached 96,380 MIG (millions of imperial gallons) in 2012. This quantity is equivalent to 412,745,123.5 m^3 of water, which is an impressive 1,13 million m^3/day. During the same period, the number of consumers increased by 191,5% and reached 554,985 in 2012, as shown in figure 2.

Figure 2. Number of water consumers in Dubai, 2001 through 2012. Data obtained from http://www.dewa.gov.ae/aboutus/waterStats2011.aspx.

Although the increases in water production and demand exhibit a strong statistical correlation (0,959), it initially appears that water production has lagged demand because the number of consumers has increased faster than the total water production. However, merging these two datasets yields a third metric, the evolution in *per capita* water availability, which better reflects water deficits or surpluses.

Figure 3. *Per capita* water availability in Dubai, 2001 through 2012. Data obtained from http://www.dewa.gov.ae/aboutus/waterStats2011.aspx.

Indeed, the figure 3 shows a gradual decline in *per capita* water availability over the 12-year period. If the number of consumers is increasing faster than water production, we might infer that Dubai will inevitably suffer from water scarcity in the future. However, the emirate has been able to provide more than 1,000 m^3 of water per person (1,048.35 m^3/person/year on average), thereby maintaining a comfortable surplus despite the increasing demand, as shown in figure 4.

Figure 4. Annual surplus water production in Dubai, 2001 through 2012. Data obtained from http://www.dewa.gov.ae/aboutus/waterStats2011.aspx.

On average, the water surplus was approximately 12% during this period. This percentage is clearly significant when one considers that the natural availability is less than 100 m^3 of water per inhabitant per year. The average availability of more than 1.000 m^3 of water per inhabitant per year is similar to that of Denmark (1.128 m^3 per inhabitant per year) and South Africa (1.154 m per inhabitant per year), according to Smith (2008, p.132). Therefore, we conclude that water scarcity has been effectively eliminated in Dubai.

Comparing the amount of water produced by desalination systems with that obtained from groundwater sources, we will now demonstrate that groundwater will not be required in the near future.

The figure 5 reveals a clear and increasing preponderance of desalinated water and a decreasing reliance on groundwater.

Figure 5. Contributions of desalination and groundwater to total water production in Dubai, 2001 through 2012. Data obtained from http://www.dewa.gov.ae/aboutus/waterStats2011.aspx.

In 2005, 99.29% of all water consumed in Dubai came from desalination plants. Although groundwater production increased briefly (reaching 4.49% in 2010), these sources appear to have been largely exhausted. Although the contribution of groundwater varied somewhat over the last 5 years of this dataset, it decreased by 79.1% overall within the study period. Because of a lack of data, we cannot statistically predict precisely when groundwater will cease to contribute to water production. Nevertheless, a tendency toward the elimination of groundwater sources is evident. When this event occurs (most likely within a few years), the human population of Dubai will have achieved complete independence from groundwater sources.

IV Perspectives

According to data from the IDA (2013a), the total global desalination capacity in 2011 was 66.5 million cubic meters per day. This capacity was provided by 16,000 thousand plants distributed among 150 countries. This desalinated water completely or partially supplies the needs of approximately 300 million people. Although these figures appear large, they are likely to increase rapidly once desalination technology becomes more efficient and inexpensive. Patricia A. Burke, the IDA Secretary General, has said that

> *"The desalination industry has done much to lower the cost of desalination by developing technologies that lower energy*

> *requirements, implementing practices that achieve greater operational efficiency and adopting measures to enhance environmental stewardship".*(IDA, 2013b)

For example, the energy required for the RO (reverse osmosis) process has been reduced significantly at the Sharqiyah Desalination Plant in Sur, which is a coastal city in Oman. According to Michel Morillon (2012, *pers. comm.*, 30th May), the engineer charged for the Sur Plant construction, if it was required, ten years ago, 15 kW (kilowatts) to produce 1 m^3 of fresh water, only 3.5 kW is needed to produce the same m^3 today. Thus, production is approaching the minimum limit of 2.5 kW per m^3 of freshwater. This reduction has been achieved through technical solutions and new procedures. For example, pumping water from 80-m-deep beachwells rather than directly from the ocean can eliminate the need for a first filtering because the well water is of higher quality, with low turbidity and silt density. Another method to optimise energy use is the Energy Recovery Device, which recovers mechanical energy from the extremely high density of the wastewater (brine), thus reducing the energy required to produce each m^3 of freshwater by as much as 40% compared with conventional plants.

In addition to these relatively simple technical procedures, more sophisticated desalination techniques have been developed and gradually introduced. To date, RO and MSF (the Multi-Stage Flash thermal process) account for 60% and 26% of the installed desalination capacity, respectively. Today, however, new technologies promise increased filtration efficiency and, consequently, reduced energy demand. According to Goh and Ismail (2013) *"… the revolution of desalination technology using CNT (carbon nanotubes) materials to mitigate few raised over concerns, particularly energy issues, seems a viable option."* Similarly, Buonomenna (2013) has optimistically observed, *"… nanotechnology has opened the way to* *produce nano-enhanced membranes (NEMs), i.e., membranes functionalized with discrete nanoparticles or nanotubes"* The membrane filtration process is strongly linked to energy consumption and costs because filtration requires significant energy input and represents the greatest fixed cost of the desalination process.

Scientists from many countries have joined the MEDRC (Middle East Desalination Research Center) in researching and developing new technologies to lower costs and energy demands and increase efficiency. Moreover, on-going research projects intend not only to reduce energy consumption but also to replace fossil fuels (oil and gas) with renewable energy sources in the desalination process. According to Subramani (2011), *"Utilization of energy efficient design combined with high efficiency pumping and energy recovery devices have proven effective in full-scale applications"*. Important results have been achieved in this field. The Kwinana Desalination Plant in Australia is entirely powered by wind energy and provides 20% of Perth City´s freshwater requirements. A 48-wind-turbine farm generates as much as 80 megawatts, which is sufficient to produce 40 million gallons of drinking water each day (IDA, 2013b).

V Conclusions

Natural water scarcity cannot be conceived on a global scale because water is one of the most abundant resources on Earth, and water scarcity is a social rather than a natural phenomenon on regional and local scales. Therefore, we conclude that the idea of natural water scarcity is largely untenable. Because of the enormous quantity of water on Earth, considering the depletion of water stocks is not reasonable.

As the empirical example of Dubai confirms, significant quantities of freshwater can be produced. Thus, water resources should join the same category as mining or agricultural resources, for which humankind manipulates natural processes to respond to human needs.

Under this paradigm, water is not merely a renewable natural resource but a *producible* one. Finally, if freshwater can be produced at decreasing expense from an unlimited source (the ocean) and through the use of renewable energy, then water can be considered both a *producible* and *inexhaustible* resource. Hence, we can expect adequate global water supply for the foreseeable future and discard the notion of natural water scarcity.

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Figures

Figure 1

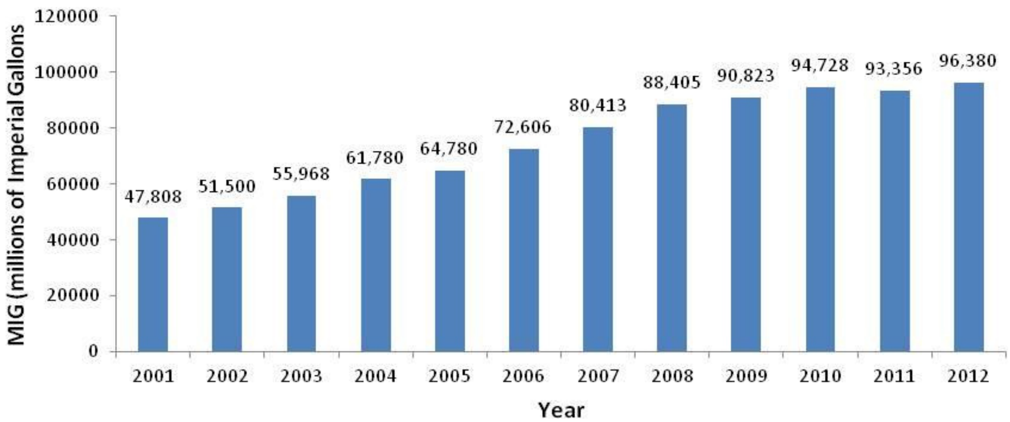


Figure 2

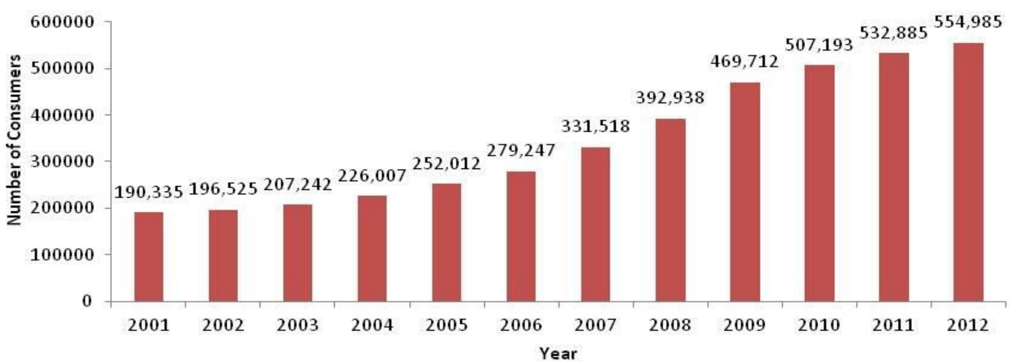


Figure 3

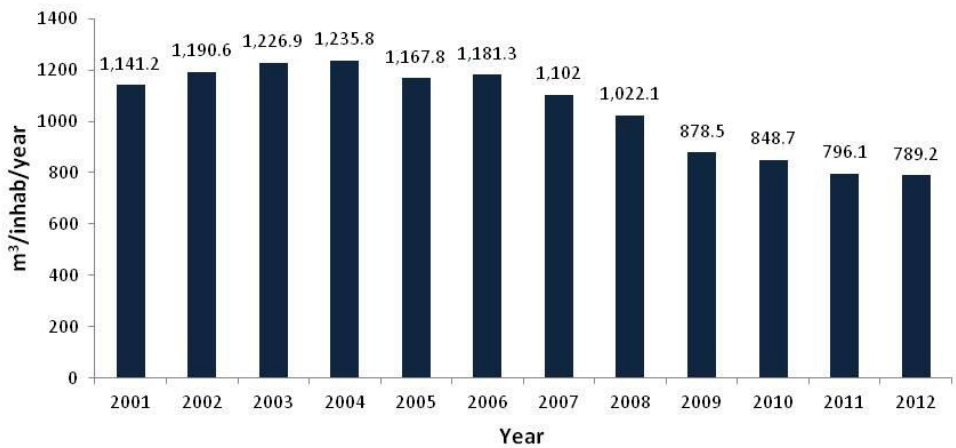


Figure 4

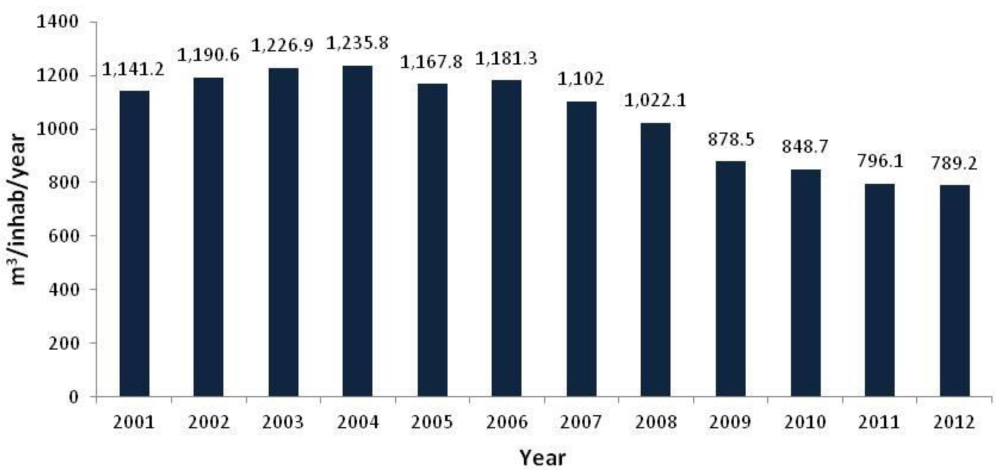
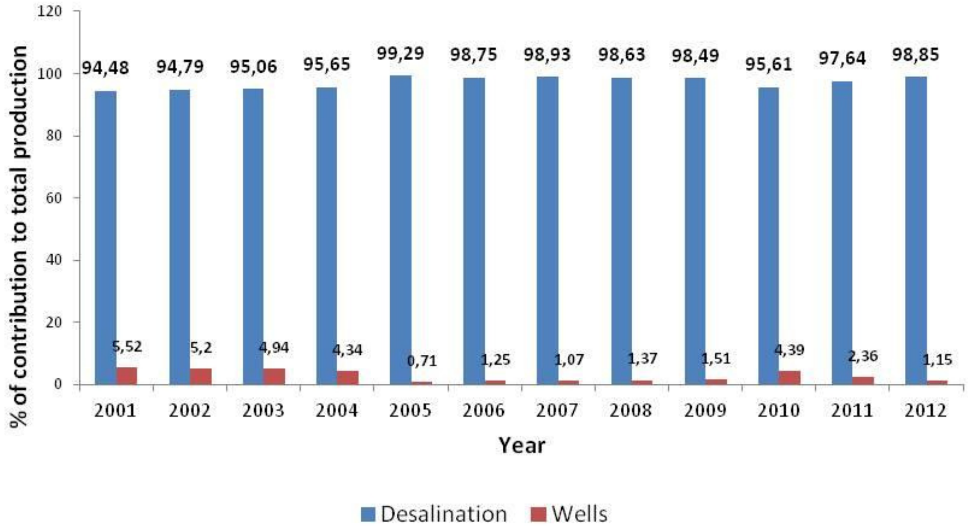


Figure 5


120
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