Voluntary Water Credits for Sustainable Desalination

Environmental Impact Offsets

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Introduction

A combination of unprecedented climatological impacts and poor water management has created an ecological crisis across the globe. Of the domestic regions most impacted, the southwestern United States stands out. With a naturally arid climate, the Colorado River Basin's economies and ecologies rely on melted snowpack and rainwater runoff from the Rocky Mountains flowing through the Colorado River. As the primary water source for seven states, the Colorado River has been drained beyond its limits and is unable to provide enough water for the two dams and over 40 million people who depend on its flow.[1] The Doheny Desalination Plant (Doheny) in Dana Point, California aims to provide a sustainable solution to the ongoing water insecurities in the region.

Desalination is the preeminent solution to the freshwater crisis. Utilizing otherwise undrinkable water, desalination produces clean, potable water for human use. With the ability to take the world's most abundant resource, the ocean, and turn it into freshwater, desalination can help avoid the snowballing impact of a collapsed water system. Despite its potential, there are valid environmental concerns associated with desalination technologies. Primarily due to the high energy consumption and by-products of the process.

This Research Brief assesses the potential of integrating a water credit (WC) market to facilitate the growth of an economically lucrative and sustainable desalination industry. WCs would facilitate the growth of sustainable desalination through incentivization and differentiation. Incentivization refers to the monetary motivation to build sustainable desalination when provided the economic leverage to do so. Whereas differentiation refers to the potential for municipalities and institutions to build portfolio standards thereby building a sustainable water program under their purview. This paper will assess the potential for a voluntary water market to facilitate the growth of a sustainable desalination industry by increasing capital and profit while reducing the environmental footprint, with a primary focus on the Doheny Desalination Plant in Dana Point, California. At a time when desalination plants and researchers are iterating on desalination technology and its environmental impact, the introduction of water credits stands only to expedite the path toward implementing sustainable desalination infrastructure.

Desalination

Desalination is the process of removing total dissolved solids (TDS), or salts, metals, and other minerals, from sea or brackish water. Most desalination technologies have either membrane-based or thermal-based desalination mechanisms. Membrane desalination technologies, such as reverse osmosis (RO), nanofiltration (NF), and electrodialysis (ED), desalinate water as it passes through a membrane.[2] RO is the dominant desalination technology in the United States, and in 2020, 60% of desalination technologies in use globally were membrane-based.[2] Thermal desalination purifies feed water through evaporation and condensation, requiring large amounts of thermal energy in the process. RO is utilized over thermal technologies due to its cost, comparatively low energy requirements, and efficient recovery rate.[3] Doheny utilizes RO as its method for desalination.

RO, while more sustainable than thermal desalination, still has an environmental footprint. As with thermal desalination, chemicals used in membrane desalination collect in the brine stream, or saline solution by-product of a desalination process, which is itself toxic to marine life. These by-products often re-enter seawater post-desalination, which can significantly and negatively alter marine ecosystems. From desalination outputs (e.g., reject brine or chemical waste) contaminating marine life to cradle-to-gate energy consumption, both membrane and thermal-based desalination technologies have room to improve as a sustainable solution to potable water scarcity.[4]

As the first project in the state of California to fully comply with the California Ocean Plan, Doheny has already implemented innovative technologies to prevent unintended, negative ecological consequences. For example, the plant uses slant wells designed to collect ocean water from beneath the seafloor and pull it through sand, which eliminates risks to sea life associated with water uptake, and disposes of brine through a wastewater outfall pipe. Doheny is at the forefront of a sustainable desalination industry and still stands to gain from the integration of water credits.

Water Credits

WCs are a voluntary market-based instrument that represent the ownership rights to the environmental and other positive attributes of renewable water generation. Each WC certifies that a unit of additional potable water was generated from a sustainable water source, such as saline groundwater using renewable energy-powered desalination. The WC specifies all the attributes of the water, such as the location, type of water treated, Carbon Footprint, capacity of the desalination plant, delivery point, and quality of the water.

For more background information on Voluntary Water Markets please visit the previous Boundless and Wacomet publication at: Voluntary Water Credits for Achieving Water Neutrality.

Leveraging Water Credits for Scaling Sustainable Desalination

The emissions profile of desalination technologies has been well-documented [5,6,7] with the majority of environmental impact occurring during the operations phase, attributed to energy use and/or brine disposal. According to the United States Environmental Protection Agency (US EPA), WCs can encourage private investment capital, provide additional resources for conservation, and serve as a catalyst for developing innovative, practical solutions for improving water quality at a lower cost.[8] The Water Benefits Standard (WBS), developed by the Gold Standard Foundation, has also improved water quality and water access in communities experiencing potable water shortages.[9]

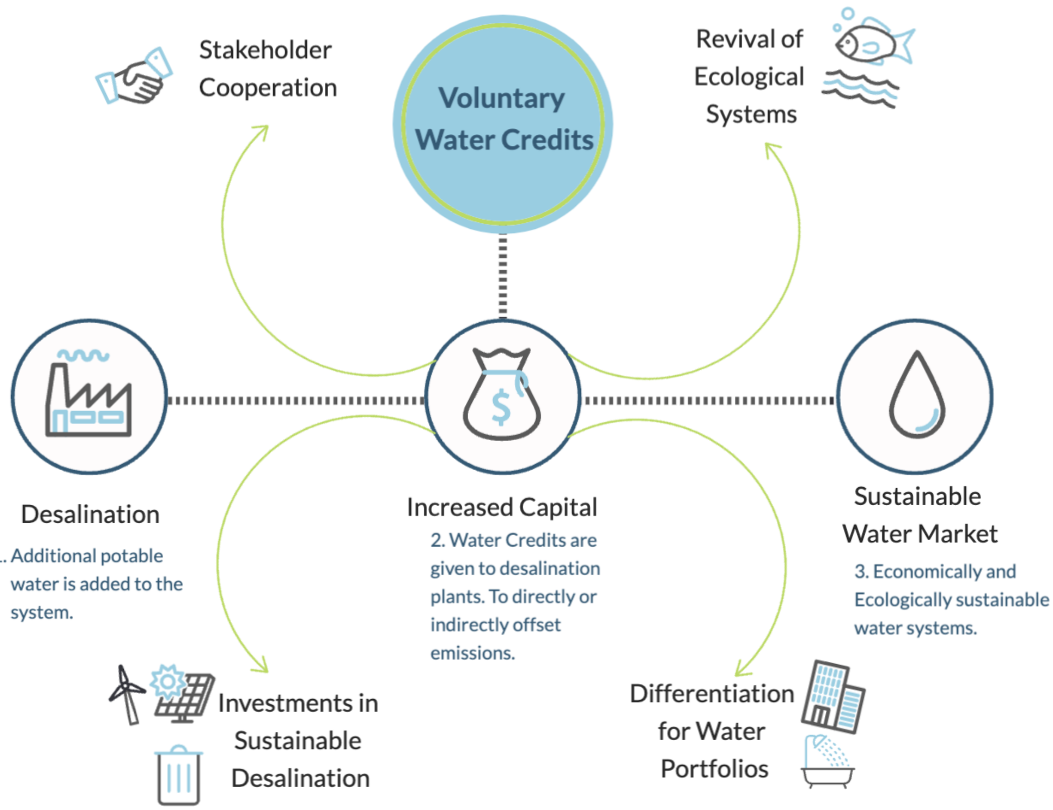
Technologies to reduce the environmental footprint of water desalination exist and can be implemented with assistance from a WC market. Hybrid desalination technologies, which use two or more desalination technologies at different stages of a desalination process, are making desalination more optimized for sustainability. Companies are adopting renewable energy to fuel desalination processes, which significantly reduces desalination technologies' environmental footprint.[2] Traditional plants can also optimize for environmental efficiency by implementing graphene oxide to make reverse osmosis and membrane distillation a more sustainable option by adsorption and photocatalysis of water pollutants,[10] or by applying brine management technologies to minimize rejected brine as an output of desalination.[11,12]

The problem lies with the integration of these technologies; optimization is costly and will require an endorsement and adoption from industry leaders and early movers. Water credits can incentivize developers to build more sustainable desalination by providing a route to turn desalinated water into a tradable commodity. The credit holder can offset pollutants up to a certain limit or sell unwanted credits for additional capital. Developers could directly offset emissions or sell credits and use the increased capital to invest in sustainable technologies, thereby reducing their footprint and increasing their potential for future credits. When implemented correctly, water credits can even decrease water extraction rates and recharge aquifers.[8]

Differentiating sustainable sources of water from those that drain stressed ecosystems is imperative to the fight against water insecurity. Because the physical (metered) water received from the local utility does not specify the water's origin or whether it comes from a sustainable source, WCs serve as an accounting tool to track and assign ownership to the distributed generation and use of sustainable water. WCs are an entirely voluntary instrument for consumers to substantiate additive or water neutrality claims. Municipalities and institutions alike will then have the capacity to build portfolio standards, declaring a percentage of sustainable water and validating that promise through the purchase of water credits. Similar to renewable energy, states could require that a percentage of water supplied by utilities come from sustainable sources, driving investment dollars towards the continued development of sustainable desalination.

Voluntary credit markets have been shown to reduce environmental footprints, increase profit, and provide local jobs.[13] Carbon credit and penalization schemes have been implemented and assessed across the world [14,15,16] to varying degrees of success. The result of this is an enumeration of successful schemes and elimination of those with unintended social consequences (e.g., increasing urban-rural gap and unfair wealth redistribution).[5] Learning and building from the foundation of carbon credit markets will allow WCs to build an avenue for the growth of a sustainable desalination market.

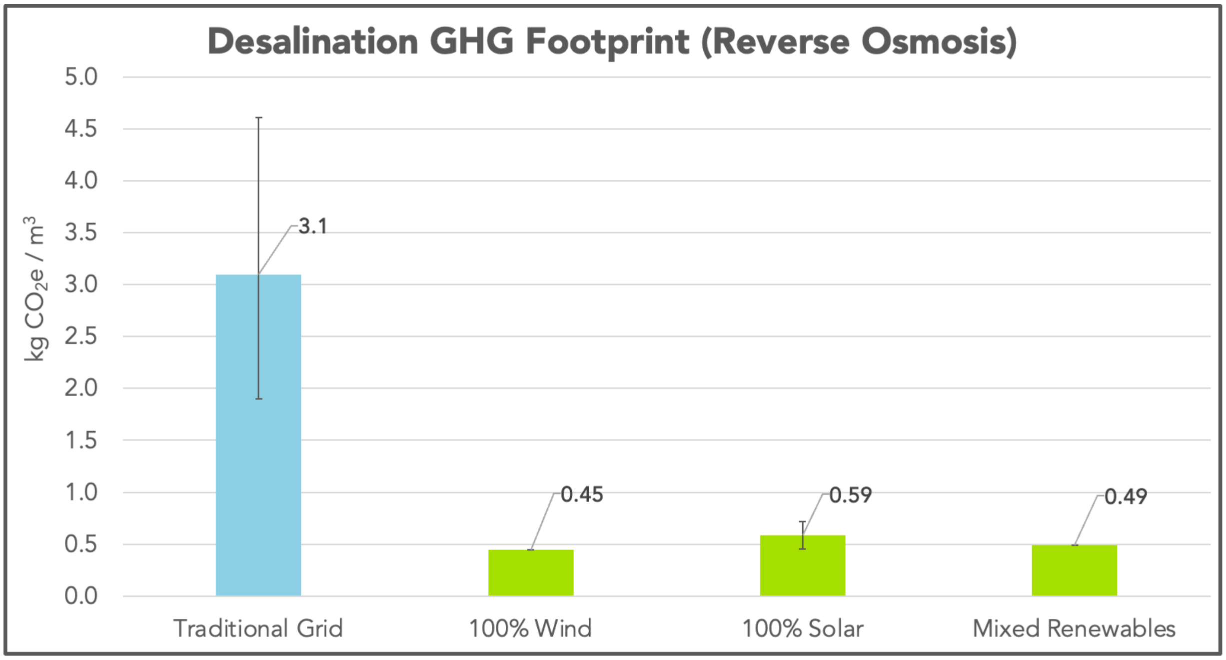
Voluntary Water Credits on the Pathway to a Sustainable Water Market



Clean Energy:

More than 90% of the environmental load associated with desalination comes from the operations stage of a plant.[17] Operations is the largest contributor in almost all impact categories including acidification potential (AP), eutrophication potential (EP), global warming potential (GWP), marine aquatic ecotoxicity potential (MAETP), terrestrial ecotoxicity potential (TETP), photochemical oxidant formation potential (POCP), freshwater ecosystem impact (FEI), and human toxicity potential (HTP).[18] Because the impact is driven by high energy consumption, implementing renewable power sources and removing a reliance on traditional energy grids can significantly improve the profile of a desalination plant.

The graph below indicates emissions reductions potential under different energy sources for reverse osmosis desalination plants across the globe, measured in kilograms of carbon dioxide equivalent (kg CO_2e) per cubic meter (m^3) of water. When using renewable sources, the environmental footprint of reverse osmosis technologies can be reduced by 85.6%, 81.1%, and 84.1% for wind, solar, and mixed renewables, respectively. This assessment utilizes a cradle-to-gate system boundary including the highest impact contributors - the operational and construction phases of the plant.



Similarly, reports have shown that electricity grids highly dependent upon nuclear power or hydropower, such as the French grid (11.5% thermal, 73% nuclear, 15.5% hydropower) or Norwegian grid (0.5% thermal, 0.5% nuclear, 99% hydropower), can significantly reduce emissions associated with RO technologies.[26,27,28] Despite a clear environmental benefit, the costs associated with renewable desalination restrain advancement by increasing the price of water.[19] As costs associated with running the plant increase, the price of desalinated water rises, unless offset by additional resources. Increased capital through a WC market could allow developers to seriously consider implementing these technologies.

Brine Management:

Due to the significant, negative impacts of the desalination waste stream, brine management must be evaluated when considering environmental offsets for desalination. Brine is essentially any high-concentration solution of salt in water and can reduce the amount of dissolved oxygen in seawater, leading to hypoxia in marine organisms. While these salts can take many forms, the common precipitate of magnesium oxide (MgO) has often been a concern due to its toxicity in ecosystems.

While not as simple as implementing clean energy to offset impacts, industry-wide brine management has made significant progress in recent years. Previously implemented methods include sea disposal, land disposal, evaporation, membrane distillation, forward osmosis, deep electrodialysis, capacitive deionization, well injection, and sewage disposal.[20] The Doheny Desalination Plant utilizes RO, which discharges denser brine concentrate as it results in a higher recovery ratio in comparison with conventional technologies. Because of this, Doheny has elected to co-mingle brine with treated wastewater in the San Juan Outfall (an existing outfall pipe) thereby diluting the solution and diminishing its environmental impacts.

The future of brine does not have to trend towards disposal. With additional resources, plants could develop ways to utilize brine as a co-product of the reaction and not just waste. Experts have assessed the potential to use brine to generate electricity by utilizing the salinity gradient potential. Research has even claimed that it is possible to produce 60% of global electricity demand by harnessing the salinity gradient potential (SGP) in brine.[19] We also have yet to fully harness the potential to mine valuable minerals out of brine. For example, MgO can be utilized in ocean alkalinity enhancement (OAE) reactions to form bicarbonate through reactions with CO_2 in ocean water.[21] The bicarbonate produced can then be used to stimulate growth of shellfish, corals, and other bicarbonate dependent organisms. Research published as early as 1999 in the Journal of Limnology and Oceanography confirms that additional bicarbonate in amounts of two millimolars (mM) caused a doubling of the skeletal growth rate of the coral.[22] Ocean Carbon Dioxide Removal (OCDR) is an evolving and expanding industry with the potential to reshape how we approach carbon drawdown. This is just one pathway towards a more sustainable economy as the potential co-benefits of each technology are still being discovered. However, one thing is for certain, to encourage a flourishing sustainable circular economy we need to get capital into the hands of those doing the work. A lack of adequate funding sources has made it difficult to develop an economically feasible version of these solutions. Water Credits could be the funding source desalination needs.

Co-Benefits to Water Credits

Beyond their economic and development potential, WCs can facilitate social benefits and further environmental justice initiatives. Credit-based systems have been utilized to build social capital between stakeholders. Water credit debates in Ohio have built a partnership with the agricultural sector, long opposed to the program. The Great Miami River Watershed Water Quality Credit Trading Program managed to convince farmers to support the initiative by negotiating an exemption for the next ten years, providing the agricultural sector with a cushion to evolve over time. Since the agricultural sector is responsible for 80% of California's water use, partnering the agricultural sector with the private technology sector is necessary and could see a significant reduction in water use. Point source polluters have also been incentivized to join a water credit market through profitable trading ratios offered to early movers in the space. By limiting this offset to a specific timeline, stakeholders were encouraged to move quickly in joining the market.

Many credit systems also require that sustainable initiatives align with the United Nations (UN) Sustainable Development Goals (SDGs). In the United States, credits can require an alignment with the Justice 40 initiatives outlined in the Inflation Reduction Act.

Conclusion

In 2023, the UN reported that by 2030, global fresh water demand is projected to exceed supply by 40%.[23] This expectation can be attributed to exponential population growth alongside declining quality of surface and groundwater. Participants in the March 2023 UN Water Conference adopted the Water Action Agenda, signaling an international push to address the global water crisis. Only 3% of water sources globally are potable. The World Health Organization advises that to qualify as potable, the salinity of water should be less than 600 milligrams per liter (mg/L). The salinity of seawater is on average 24,000 to 42,000 mg/L. Desalination technology is needed to unlock the vast supply of seawater as a potable water source. Desalination plants are key players at the forefront of future water supply.[13] Without an additional source for water supply we currently see three options for California:

1. California reduces its water usage either voluntarily or by federal order, which would likely result in a prolonged legal dispute between the state of California and the federal government.

2. The remaining six states that rely on the Colorado River (Arizona, Colorado, Nevada, New Mexico, Utah

and Wyoming) take a broader water cut to mitigate California's refusal to reduce. This may be difficult because all other states are currently using drastically less water than their original allocation.

3. The river is drained beyond its capacity to replenish resulting in dead pool. This is the worst-case scenario. Overexploitation of water resources and noncooperation from the states would mean there isn't enough water to flow out of the dams from Lake Mead and Lake Powell. This could turn off river supplies to millions of people, including cities such as Las Vegas, Los Angeles, and Phoenix.[24]

The Colorado River supplies 4.4 million acre-feet (MAF) (5.4 km^3) of water per year to California;[25] if we wanted to completely remove California's dependency on the river system there would need to be an additional 4.4 MAF in desalinated water production. However, a single desalination plant, on average, can currently be expected to produce roughly 50 million gallons of water per day, equivalent to 153.5 AF. In a year, an equivalent desalination plant could supply roughly 56,000 AF, meaning at current numbers California would need around 79 additional facilities to generate enough fresh water to remove California's dependence on the river system. In order to accomplish this feat, sustainable desalination will need to be provided the opportunities to evolve. Water Credits can be the pathway to sustainable desalination that solves the water crisis.

About Boundless Impact Research & Analytics

Boundless Impact Research & Analytics is a market intelligence and impact analytics firm that provides quantitative and evidence-based research and data for investors, companies, and funds. Driven by the latest research from independent industry and academic experts, Boundless Impact Research & Analytics offers analysis, market trends, and evidence of best practices in a growing number of emerging sectors that address significant environmental challenges. Our research into emerging technologies, impact assessment of companies, and thought leadership provide investors with the latest and most relevant information to drive their investment decisions.

About Wacomet Water

Wacomet Water is a provider of distributed desalination technology to regenerate water. Wacomet was founded in 2022 to redesign our water infrastructure by pioneering the integration of advanced desalination and sustainable energy. Wacomet believes that humanity's greatest scientific achievement will be the conversion of unlimited saltwater into clean, affordable, scalable freshwater. Wacomet aims to achieve this by reimagining distributed water generation, advancing the frontier of desalination process innovation, and creating a platform where anyone can benefit from additional water. Wacomet believes in the relentless pursuit of water abundance and our capacity to permanently eliminate global water scarcity.

About WaterDAO

WaterDAO is short for Water Information Certification Systems DAO LLC, an open-source entity that is autonomously managed by smart contracts. The purpose of WaterDAO is to better enable Voluntary Water Markets by creating a standardized protocol for classifying and measuring the beneficial attributes of regenerative water. This protocol, R-H2O (which stands for regenerative water), conveys ownership over the beneficial attributes of regenerative water, such as sustainable desalination. R-H2O acts as a transparent, certified, and verifiable water credit for qualified water sources and is only created when an additive unit of water has been generated from a validated source (1 R-H_2O = 1 m^3 water).

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