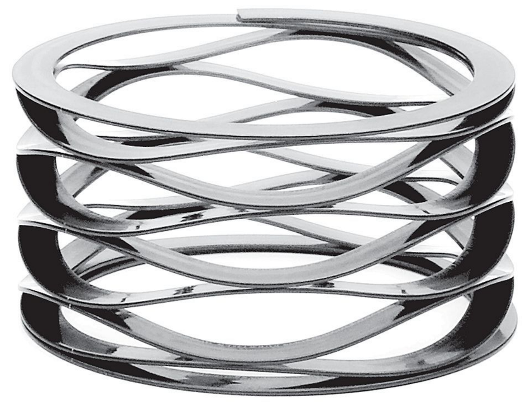
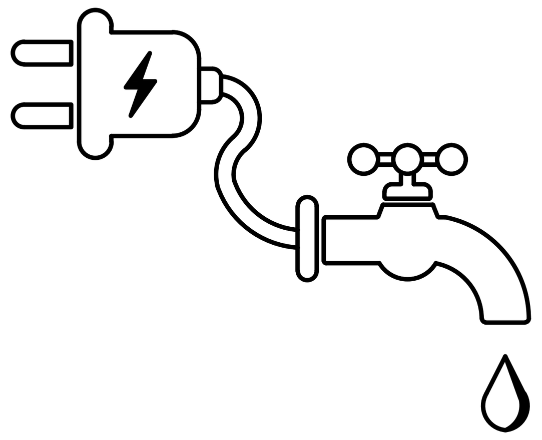
Parasitism vs. Altruism

In nature, it is not unusual for two different biological species have a close interaction between them; this is referred to as symbiosis. Mutualism describes such a relationship when both individuals benefit from their interaction. Reciprocal altruism is an extraordinary case between species, it occurs when the relationship is obligate, meaning that both symbionts entirely depend on each other for survival. In our world, the management of water and energy conduct a symbiotic relationship that is referred to as the water energy nexus. However, in an analogy to the biological world, this bond typically resembles parasitical symbiosis where, in turns, one specie completely exhausts the other.

Water Energy Nexus

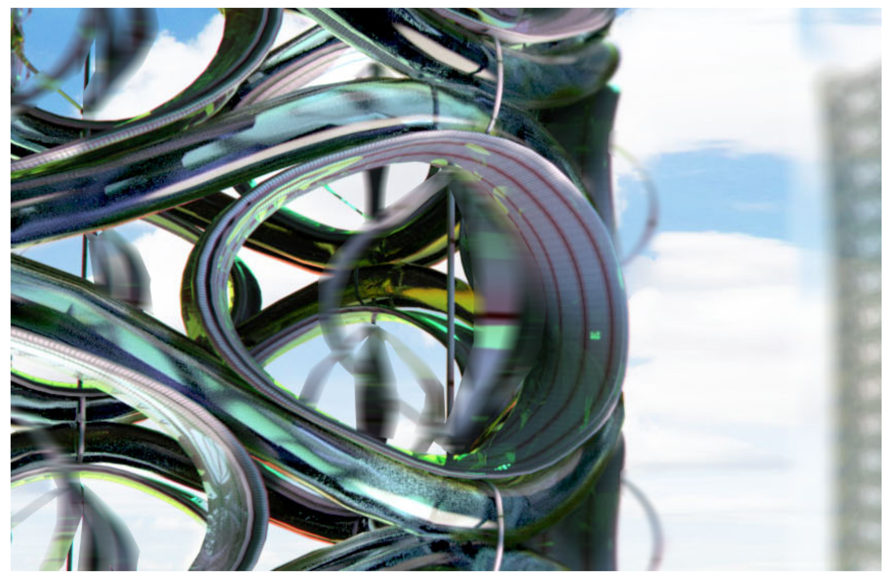
In the state of California, about 12% of the total energy used is related to water, that's about 300 million MWh of energy per year!! On the other hand side, it is estimated that for each 1kwh that we consume between 11-25 gallons of water are lost!! It is impossible to fully quantify these colossal amounts and even harder grasp them. Nonetheless, it is clear that even a fraction of a percentage of change in this relationship would make a huge difference. A sustainable vision requires a re-evaluation of the use of our vital recourses. It promotes locality and supports autarkic methods that reduce redundancy and lead to energy / water independence. It encourages system integration and the desertion of squandering infrastructure. It favors innovative technologies and advocates novel aesthetics that reflect its values. Perhaps with backwind of the California state sustainability vision and municipal initiatives, the water energy nexus can shift away from reciprocal parasitism and endorse reciprocal altruism.





Sustainable Challenges

Two of the crucial engineering challenges of our time include transitioning to clean, renewable energy systems, and securing adequate freshwater supplies via efficient water desalination systems. While renewable energy systems, such as solar panels, wind and hydro turbines are widely available, their intermittent nature currently limits their penetration to roughly 5% of the electricity generation in the United States, whereas fossil fuels such as coal and natural gas account for approximately 65%. If these renewable energy plants were coupled to a low-cost and high performance energy storage system, which could, for example, inexpensively store the excess solar energy captured during the day and deliver it at night, then the penetration of these renewables would grow substantially.



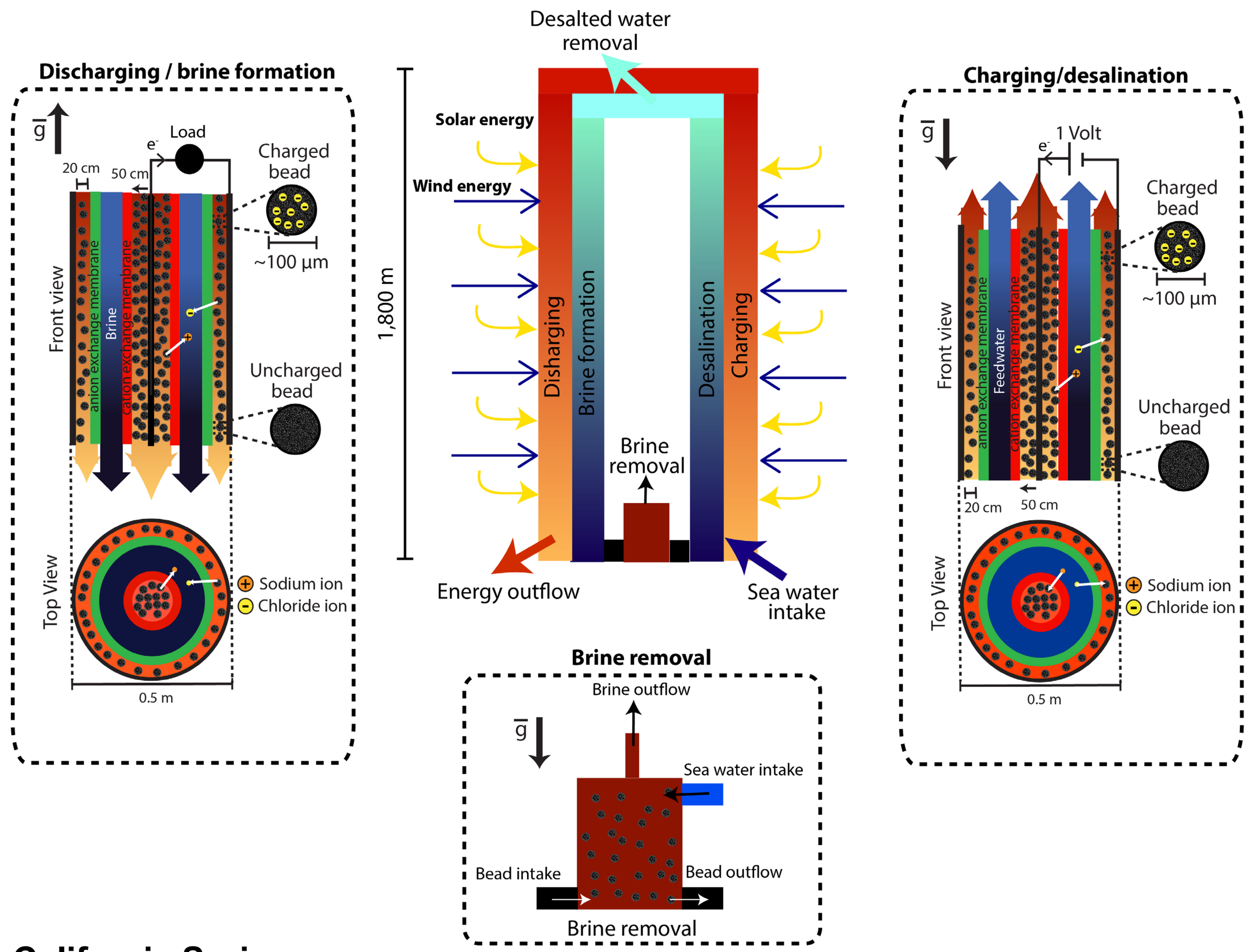
Structure

A wave spring is helical spring with added wave shaped bends, these make it possible to accommodate higher thrust load within the limited axial space in comparison to the helical spring. This is an important factor considering the load of the water in the pipes. It also increases the length of the pipe which maximizes the desalination process. The flexible water pipe is made of extruded plastic, its diameter is 0.5m and its total length is 3,600 meters. The "eyes" of the spring are formed by metal rims similar to those on the wheels of a car. Each junction of the wave spring ties together 4 pipes, these are "soft joints" that allow the structure to gently bend and sway with nature's forces. The foundations of the structure allow the spring to flex in accordance to the harsh marine environment.

Capacitive Deionization - CDI

The Californian cost is blessed with a variety of sources for renewable energy - sun, wind, waves and tides. Technologies for harvesting energy from each of these sources have been developed and applied for decades. Nonetheless, despite leaps throughout the spectrum of renewable energy, no matter the method that is deployed to harvest energy, the Achilles heel is managing the cache and exchange of the produced electricity. A surprising yet simple solution arrives from across the equation of the of the water energy nexus. A new, emerging technology, Capacitive Deionization (CDI), can simultaneously store energy and desalinate water, and thus can serve as the technological foundation for our evolving energy and water needs.

In CDI, we perform water desalination by charging a cell using an applied voltage of about 1 Volt. As CDI is classified as an electrochemical system, similar to a battery, CDI cells can store energy while they are being charged. The energy can be recovered at the end of the process, similar to utilizing energy from a discharging of a battery. Further, due to its unique, low voltage input requirements, CDI can be easily integrated with renewable energy sources, such as solar panels and wind turbines.



California Spring

These features of a CDI system are maximized in the proposed infrastructure. In this design, CDI cells are designed as column-based springs rising from the seabed. The columns contain integrated wind turbines and solar panels as well as wave and tide turbines to power the water desalination process. Furthermore, the columns store up to 80% of the energy used in the desalination process, which can be recovered at the end of the process to power the pier.

The term spring is a homonym charged with associations that compiles an unlikely family of symbiotic siblings. Mechanically, the spring is an elastic device used to store energy. In hydrology, the spring is a natural source of water. Spring also refers to the season associated with renewal. All these attributes manifest the California spring - a standalone plug in plug out infrastructure based on reciprocal altruism between water and energy by means of innovative technology.

Energy Calculations

The energy store in a charged capacitor is given as $E = 1/2CV^2$, where C is the cell capacitance, and V is the cell voltage.

The conservative capacitance of the carbon beads used is C = 100 Farads per gram of carbon. The cell voltage used will be 1 Volt, roughly the output voltage of the solar panels.

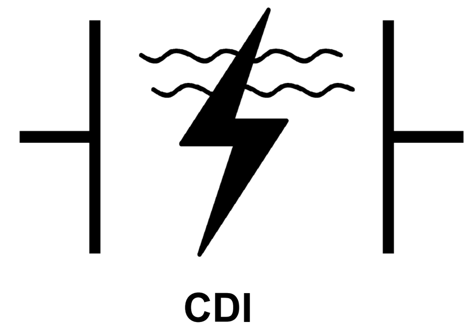
The typical volume fraction, ϕ,of the beads in the channels can range from about 20% (downhill flow) to about 70% (uphill flow). We will use the number of $\phi = 45$ here as an average volume fraction in the system

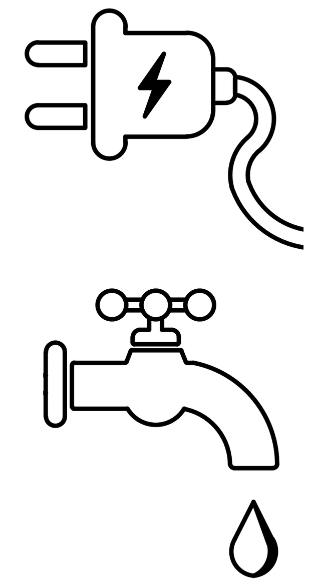
The density of the carbon beads is roughly $\rho = 1.3$ grams of carbon per mL. The channels which the beads flow through include the inner channel with radius of 0.1 m, and the outer annular channel with inner radius of 0.23 m and outer radius of 0.25 m. thus the total area of bead flow is 0.0628 m2, and the length of the channel is 1800 m.

Thus, the final calculations shows that

$$E = 1/2CV^2\varepsilon = 1/2C_{sp}\rho\phi ALV^2\varepsilon$$
$$= 0.5*100F/g*1.3g/mL*1000^2 mL/m^3*0.5*0.0628\,\mathrm{m}^2*1800m*1.5^2V^2*1J/3.6E6kWh$$
$$= 2296kWh$$

Thus, approximately 20 charging springs can store the required daily energy of the pier





Water Calculations

Let's calculate the volume of water in the system, which consists of 20 springs. The feedwater channel is 1800 m long in each spring, and it is an annulus with inner radius 0.1 m and outer radius 0.23 m (neglecting the membrane thickness, as they are typically less than 1 mm thick). Thus, the total water volume in the system feedchannel at any one time is:

$$V = \pi(r_o^2 - r_i^2)Ln$$
$$= 3.14*(0.23^2 - 0.1^2)m^2*1800m*20*1000L/m^3/(4L/Gallon)$$
$$= 1.2E6\ Gallons$$

The water requirements for 2000 houses at 500 Gallons/day usage gives a requirement of 1E6 gallons/day for treated water. Thus, the system of springs contains about the same water as is needed for the 2000 houses. Thus, we need to replace the water in the feed channels once per day (~1E6 gallons per day throughput from the system of springs)

Santa Monica Pier

The history of Santa Monica Pier teaches us about the creative pioneering minds that have wisely turned an urban necessity into a public opportunity by perceiving the construction of infrastructure as a driver for the development of an innovative public space. This action entails not only an immediate solution to a problem, but rather a long term sustainable vision. Today, well over a century after the construction of the pier, this pioneering sustainable vision continues to guide the development of the pier in the face of current and future urban challenges. The pier's iconic ferris wheel which is already the world's only solar powered ferris wheel is undergoing further improvements to make it even more efficient. Within this rich context, the spring it is another step forward in the implementation of sustainable pioneering.

Coastal Test Case

The proposed infrastructure is designed not only to cover the entire energy requirements of the pier, but more significantly to serve as a test case for the potential of the Californian coast as provider of clean energy and fresh water. The energy requirements for the pier are conservatively estimated at 50,000kwh per day, a quota provided with 10-15 springs. As an average Californian household consumes between 20-25kwh per day, this is equivalent to the daily energy needs of approximately 2,000 households. Regarding water supply, as an average Californian household consumes between 500-600 gallons per day, the water held in the system is just over 1 million gallons, which is about the volume needed by the 2000 houses.