INTRODUCTION

You fly out to Santa Monica to visit a close friend. You arrive in the morning, toss down your bags, and ask the important question, “So what are we going to do today?” Your friend smiles and tells you that you are going to love it—you are headed for the Santa Monica Pier.

You both make your way down Pico Boulevard, turn right onto Ocean Avenue, and stroll through the recently completed Tongva Park by JCFO. You admire the beautiful plants— mostly natives—that fill the bioretention swales. This is important, your friend explains, because they intercept rainwater and pollutants that would otherwise run directly into a valuable water resource—the nearby Santa Monica Bay. “Wow,” you exclaim, “I had no idea that sustainability could be so beautiful.”

Your friend replies, “Wait until you see what’s next.”

FORM & SCULPTURE

Your first glimpse of the bay comes as you pass under the historic Santa Monica Yacht Harbor sign. The first thing to catch your eye is the iconic Ferris Wheel. Then, your eye wanders across the horizon, where you see a shimmering, iridescent mirage of swirling whites, pinks, and greens. The floating forms are playful and cheery, arranged in a sinuous line that resembles a school of fish. “Those are so cool!” you exclaim, as you and your friend approach the beach. “What are they? Giant origami boats?” Your friend laughs and explains that they are called the *Paper Boats*, and they are actually solar energy collectors.

You are astounded. You need to know more. You pull out your phone and google *Paper Boats*. A website appears explaining that Santa Monica receives 281 days of sunlight a year. These sculptural solar collectors capture almost 96% of that energy by using a combination of special Fresnel lenses, reflectors, and holographic photovoltaic cells. “But why the boats?” you ponder, “I saw the sign. Is this place an actual yacht harbor?”

Your friend tells you, “No… but it was once.”

ENVIRONMENT & HISTORY

Your friend explains that there was a desire in the 1930’s to transform the pier into a thriving boating and yachting destination. A breakwater was constructed to create a protected harbor for the vessels. However, the breakwater was poorly engineered and began to sink immediately. Now completely submerged under the ocean surface, the breakwater is a forgotten industrial relic. However, the *Paper Boats* have changed all of that. Not only do they generate energy and recall the history of the pier and harbor, they are also working to transform the breakwater. “How so?” you ask.

You both reach the overlook at the end of the pier, and your friend pauses before answering. Up close, the boats are even more stunning, with their iridescent panels creating playful reflections over the water’s surface. She explains that the Boats revitalized the ecology of the area and brought back dozens of marine species that everyone assumed would never return. This was accomplished by reestablishing two vital ecosystems—a coral reef and a giant kelp forest.

You jump back to your phone to find out more and see that giant kelp forests were once commonplace in this area. However, over-hunting and over-fishing of some key species—sea otters, California sheephead, and California spiny lobster—have allowed another species, purple urchin, to graze on the kelp without competition. This has led to “urchin barrens,” which offer little in the way of genetic diversity, food, or pollutant removal. The *Paper Boats* have reversed this trend by establishing pockets of coral and kelp on underwater “shipwreck” frames that anchor each boat to the historic breakwater.

The rebar “shipwrecks” mirror the sculptures above and encourage coral growth with a phenomenon called accretion. First observed by Wolf Hilbertz, accretion is a process where a trickle of direct-current electricity (provided by the solar collector above) is run through the rebar to accelerate coral growth up to five times faster than normal. After the purple urchins were removed and the *Paper Boats* and “shipwrecks” were installed, the coral were established within two years. Shortly after, transplants of giant kelp were attached to the reef. Soon, fishermen started noticing native fish returning to the area. One blogger even says he spotted a sea otter!

PEOPLE & PROGRAM

“Besides fishing and spotting sea otters,” your friend tells you, “the *Paper Boats* offer a huge range of activities for the community and visitors alike.” She continues to describe the upcoming Tommy Bahama Paddle Board Race and Ocean Festival and how the race weaves its way right through the flowing line of solar collectors.

“Underneath the water,” your friend explains, “you can scuba dive through the kelp forests and coral reef shipwrecks during the Electric Reef Scuba Festival. The festival has become a big advocacy event, with the city embracing it as an opportunity to protect, preserve, and restore the natural environment as part of the Santa Monica Sustainable City Plan.”

“And you’ll love this last thing,” your friend says smiling. “Every Thursday from July to September, a free concert, called the Twilight Concert Series, is held on the beach. The concert used to be on the opposite side of the pier, but the city moved it to the north side to take advantage of the amazing backdrop of glowing *Paper Boats*. The light show is the perfect complement to the music.”

ENVIRONMENTAL IMPACT STATEMENT

*Paper Boats* consists of 185 sculptures situated in a loose, serpentine pattern. The simple, modular design is easily constructed, transported, and installed, keeping embodied energy to a minimum. The stern of each ship points northwest, allowing the “sails” to receive maximum solar exposure throughout the day. Santa Monica receives approximately 281 sunny days per year, as well as an average solar irradiance of 5kWh/m2/day. The site’s reflective ocean surface helps to increase this metric.

To capitalize on the sunny conditions, each boat’s four sails work as Concentrated Photovoltaic panels (CPV’s). The outer shell of the “sail” utilizes Fresnel lenses to channel incoming light. The lenses’ complex profile keeps the glazing thin while providing large apertures, cutting costs, and offering a transparent PV panel.

Beneath the sails are a series of holographic photovoltaic cells. These pair laser-etched glazing with bi-facial silicone panels that trap sunlight from both directions with incredible efficiency. The intricately cut patterns also refract light, giving them a shiny, iridescent quality that glows beautifully—especially at sunset.

The solar panels are attached to a ceramic-cladded aluminum framework. The structure conceals the CPV conduits and acts as passive heat sink.

The CPV conduits exit beneath each ship’s reflective keel into the anchoring tentacles below. These tentacles attach to the installation’s main conduit as well as the steel-framed “shipwrecks”.

A trickle of energy is diverted to the “shipwrecks” before entering the main conduit. This small charge provides a catalyst for coral growth, strengthening the local marine ecosystem. The remainder of the electricity is fed out of the main conduit at a rate of approximately 6,526 kWh/day and 2,382,000 kWh/year (the equivalent power requirement of 13 Santa Monica Piers). Additional benefits include: $650,000 of annual ecosystem services, publicity for Santa Monica, and expanded opportunities for eco-tourism.