**CETACEA**

Sunrise in Santa Monica finds two kayakers paddling in the glassy, blue-green water of the Pacific. As they make their way out into the bay, the first dazzling rays of sunlight illuminate a series of arches, glistening white, rising gracefully from the surface of the water. This is Cetacea: a beautiful integration of energy and art.

Sophisticated and laid-back, cutting-edge and rich with history, Santa Monica is a far-from-average beach town. A day on the beach can begin with parasailing around Cetacea and end with an all-night beachfront art show. Rooted in Santa Monica’s reputation as a world-class cultural destination, Cetacea embodies the city’s vibrant beachfront ambiance and its vision for a sustainable future.

Cetacea generates power the Santa Monica way. Captivating and exciting, hardworking and elegant, timely and timeless: Cetacea harvests the signature renewable resources of Santa Monica Bay—wind, wave, and sun. Driven by one principle, **clean power for clean water,** Cetacea recognizes the preciousness of water to the Santa Monica region. In order to reconcile water scarcity with pressing social and ecological concerns, Cetacea supports existing water filtration facilities close to the pier while providing carbon-neutral power to city residents. By plugging in to the Santa Monica Urban Runoff Recycling Facility (SMURRF) and providing enough electricity to run a High Efficiency Reverse Osmosis (HERO) system, Cetacea takes a bold move towards achieving Santa Monica’s 2020 sustainability goals of water and power independence.

**ENERGY PRODUCTION:**

The blue whale is a pelagic powerhouse. Consuming upwards of four tons of krill per day, the world’s largest-ever creatures are fueled by gargantuan quantities of its smallest. Cetacea reimagines the blue whale’s strategy of capturing micro-sources of energy on an even larger scale.

In place of the sprawl and unappealing profile of workaday renewable energy farms, a vertical configuration of wave-, wind-, and solar-powered generators within graceful, multifaceted arches maximizes energy production within a minimal footprint. Cetacea’s integration of renewable energy into the existing infrastructure of the SMURRF helps the city achieve its resource conservation targets for 2020 by using local power to produce clean drinking water. Modular arch components mean that Cetacea can easily be expanded in the future through the construction of additional forms, meeting the needs of a changing city while continuing to generate energy beautifully and unobtrusively. Repetition and subtle variation of the arches create ethereal forms in constant interaction with the play of sea, light, and cloud across the horizon—an enduring but ever-changing part of the Santa Monica skyline.

Cetacea combines three existing technologies within each arch, allowing for nonstop energy production:

**Wave buoys** 0.3 meters in diameter are situated within the framework of the arches, floating at sea level to capture wave energy around the clock. Buoys slide along a vertical shaft with the passing of every wave, moving a magnet through an electromagnetic coil and inducing the flow of electric current.

 Power potential per meter of wave crest:

 $P =$ ($\frac{0.5kW}{m^{3}s}$)$(1.03m)^{2}(6.8s)=(( 3.6kW⁄m × 1m⁄3.28ft))/2=\frac{1.8kW}{ 1.5'}$

Conversion efficiency of 80% allowing the buoy system to output 1.44kW per hour[[1]](#footnote-1), [[2]](#footnote-2)

Single buoy output: 34.56kWh / day

 Number of buoys: 239

 Total energy output: 8.2 mWh / day

**Windbelts**,manufactured by Humdinger[[3]](#footnote-3), are stacked within the sides of each arch at one meter intervals. Following the principles of the Bernoulli Effect, the form of the arches increases wind speed as it passes through the belts. The resulting aerostatic flutter of the belts creates energy by oscillating magnets through an electromagnetic field.

Windbelt output per linear meter: 0.2 kWh / day

 Total linear meters of windbelt: 3189

 Total energy output: 637 kWh / day

**Monocrystalline silicon photovoltaic arrays**[[4]](#footnote-4) are positioned at the top of each arch for maximum solar gain.

Solar panel energy production per square meter: 5 kWh / day

 Total solar panel area: 627m2

 Total energy output per day: 3.1 mWh / day

**Cetacea total energy output:** 11.937 mWh / day

Amount of energy required to run S.M.U.R.R.F and the reverse osmosis facility: 9.35 MWh / day[[5]](#footnote-5),[[6]](#footnote-6)

Energy surplus: 2.587 mWh / day

 **Cetacea energy output per year: 4,357 mWh**

In more concrete terms, Cetacea generates enough energy to clean and purify the 500,000 gallons of dry-season urban runoff treated by SMURRF each day. Combined with a new High Efficiency Reverse Osmosis (HERO) system (purifying water at 95% efficiency), the facility is capable of producing 475,000 gallons of potable water a day. This output meets the clean water needs for 7,327 residents—with enough energy left over to provide for 251 households’ daily electricity requirements.

**DIMENSIONS AND MATERIALITY:**

Built to last, Cetacea’s arches are constructed of recycled stainless steel frames, finished with lightweight recycled white fiberglass cladding. Structural integrity is achieved by a driven pile system utilizing recycled concrete. The minimal physical footprint of the structures allows room for habitat reconstruction, utilizing the existing breakwater to reduce the number of footings on the ocean floor. The rugosity of the recycled material below the water level allows for marine life to take hold and create new habitat patches.

Cetacea consists of five sculptures of three different sizes. Each parabolic arch ranges in height from 13 to 30 meters tall (depending on their location in the installation).

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| --- | --- | --- | --- | --- |
|  |  |  | Maximum Dimensions | Number of Productive Units |
| Size | # of sculptures | # of Arches | Width | Height | Length | Solar | Windbelts | Bouy |
| Small | 2 | 17 | 15m | 13m | 80m | 71m2 | 254m | 34 |
| Medium | 2 | 25 | 22m | 19.5m | 120m | 134m2 | 687m | 50 |
| Large | 1 | 34 | 30m | 30m | 160m | 217m2 | 1340m | 68 |

**ENVIRONMENTAL IMPACT STATEMENT:**

By localizing clean energy production and enhancing threatened habitat, Cetacea has an immediate and significant positive environmental impact in Santa Monica and the bay. While recycled steel and recycled concrete begin to mitigate the release of more carbon emissions, the embodied energy of the materials and construction processes are offset by a reduced civic carbon footprint, positive impacts on Santa Monica’s marine life, and the long lifespan of the structures.

Cetacea responds to Santa Monica’s goal of becoming energy independent by 2020, exceeding the city’s stated goal of installing 8.5 MW of solar energy citywide. Though photovoltaic cell arrays form one part of Cetacea’s energy harvesting framework, the structures avoid the high chemical and carbon footprint of unaccompanied solar power by combining three modes of energy production in each arch. The result is truly clean, renewable, beautiful power: high tech high art.

Offshore ecological restoration is a top priority in Santa Monica Bay. As the blight of urchin barrens spreads throughout the Pacific coast, Cetacea plays a part in the delicate balance of the ecosystem. The re-establishment of kelp forests in Santa Monica Bay calls for control of purple sea urchin populations. By creating grottoes and overhangs in the sculpture’s foundations, Cetacea provides habitat for sheepshead fish (*Semicossyphus pulcher*--listed as a vulnerable species by the IUCN) and Pacific lobster (*Panulirus interruptus*)--two major predators of the sea urchin. Predatory control of sea urchins gives kelp forests a chance to regrow, allowing the return of teeming ecological diversity.

1. "Ocean Power Convertor - LTC Singapore." Ocean Power Convertor - LTC Singapore. Accessed May 15, 2016. <http://lamtengchoy.com/>. [↑](#footnote-ref-1)
2. Ferry, Robert, and Elizabeth Monoian. *A Field Guide to Renewable Energy Technologies*. 2012. [↑](#footnote-ref-2)
3. "Windbelt - Reinventing Wind Power | Latest Features | Physics.org." Windbelt - Reinventing Wind Power | Latest Features | Physics.org. Accessed May 15, 2016. http://www.physics.org/featuredetail.asp?id=47. [↑](#footnote-ref-3)
4. "PVWatts Calculator." PVWatts Calculator. Accessed May 15, 2016. http://pvwatts.nrel.gov/. [↑](#footnote-ref-4)
5. "Water-Energy Connection." | Region 9:. Accessed May 15, 2016. https://www3.epa.gov/region9/waterinfrastructure/waterenergy.html. [↑](#footnote-ref-5)
6. United States. Department of Energy. Office of Energy Efficiency Renewable Energy. Saving Energy, Water, and Money with Efficient Water Treatment Technologies. Technology Focus. Washington, D.C.: U.S. Dept. of Energy, Office of Energy Efficiency and Renewable Energy, 2004. [↑](#footnote-ref-6)