Greening Aquarium of the Bay

GROUP PROJECT BRIEF

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Aquarium of the Bay

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Introduction

Aquarium of the Bay At-A-Glance

- **Owned by the Bay Institute**
- **Association of Zoos and Aquariums (AZA) accredited**
- **San Francisco Green Business**
- **Located on San Francisco's Pier 39**
- **Home to over 20,000 marine animals**
- **Receives 600,000 annual visitors**
- **Two large tunnels allow visitors to experience life beneath the Bay**
- **Dedicated to educating visitors on the importance of conservation of the San Francisco Bay**

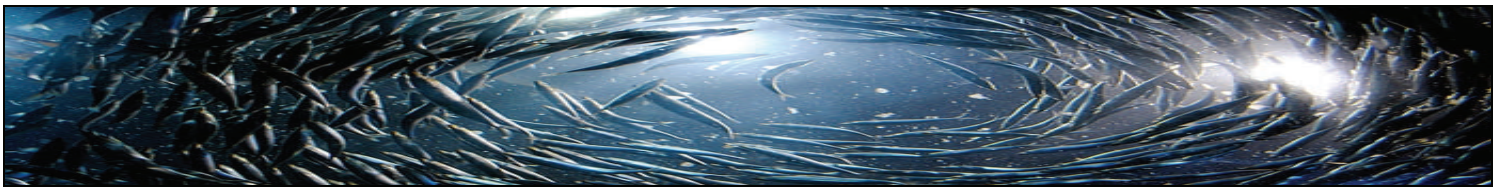
Aquarium of the Bay (AOTB) is located on San Francisco's Pier 39, drawing 600,000 visitors per year. It is owned by the Bay Institute, a non-profit dedicated to the conservation of the San Francisco Bay and its watershed. The Aquarium earned certification as a San Francisco Green Business in 2005. However, this certification only applied to retail operations, and did not take into account environmental impacts from the life support system or animal welfare. Enhancing energy efficiency in life support operations, which accounts for 89% of total energy expenditures for ATOB, provides a means for improving sustainability.

Methods for improving environmental performance were analyzed based on the reduction of carbon. emissions**,** cost -effectiveness, and impact on animal welfare. A cost-benefit analysis was performed for each recommendation, and a carbon footprint was calculated to determine emissions from electricity consumption.

In 2011, Master's students from the Bren School began a project to make improvements to the aquarium's environmental performance, focusing on energy efficiency improvements and the welfare of the facility's 20,000 aquatic animals. The two aspects of the life support systems explored were water flow rates and water temperature controls, which represent the most energy intensive processes in the Aquarium.

Objectives

- **Establish a baseline for energy use, Scope 2 CO_2 emissions, and biological health**
- **Identify new methods and processes to reduce environmental impacts and improve animal welfare**
- **Assess economic feasibility of a variety of improvement options**



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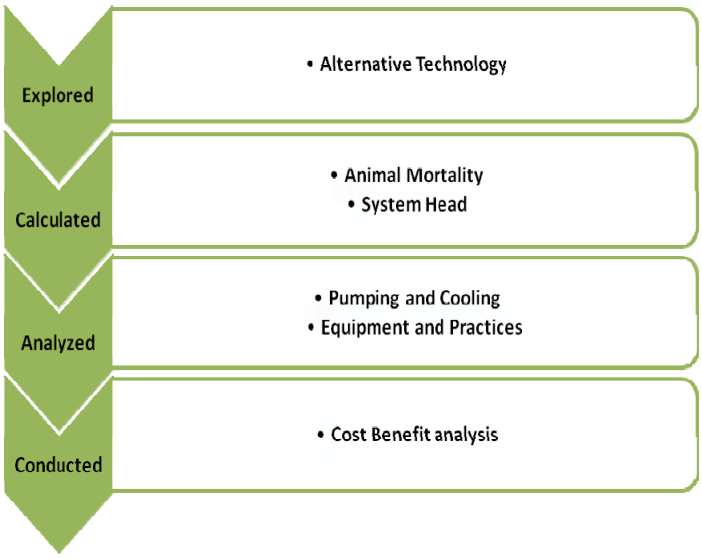
Methods



Results

Animal Care

A successful aquarium relies heavily on keep animals alive and healthy. Our research determined that some animals in AOTB commonly experience life support related deaths. Below is a solution for reducing overall mortality.

Remove Sensitive Fish Species

How it works: Some species of fish are more sensitive to temperature fluctuations in the water than others, making them prone to disease and death. Identifying and removing these species can make for a more resilient makeup of the animal population.

What we did: The various species of rockfish constitute over 50% of fish mortalities in Tank 1. Of the 21 species of rockfish, black, brown, and grass account for 50% of all mortalities. Furthermore, 72% of mortality occurred when water temperatures were above 14°C

Results: Up to 25% of Tank 1 mortalities can be prevented by removing black, brown, and grass rockfish.

Temperature Control

When water temperatures exceed 14°C, mortality and disease increase significantly. Yet, chilling is highly energy intensive: the main chiller consumes approximately 29% of life support energy. We found more efficient ways to cool water, reducing the amount of work required by the chiller.

Insulation

How it works: Insulation protects the chilled water in the pipes from exposure to heat from the ambient air.

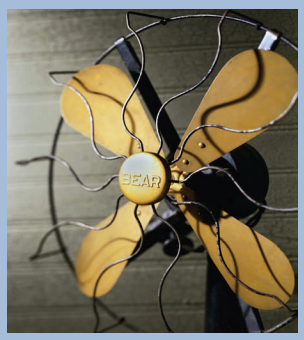
What we did: Currently, 320 million kilojoules of energy enter through the pipes from the ambient air. Adding insulation will prevent 276 million kilojoules of heat energy transfer.

Results (20 year time horizon):
CO_2 reduction = 191,861 lbs, NPV = -$195,073

Industrial Fan

How it works: Fans increase heat loss by encouraging evaporation from the main tanks.

What we did: Currently, 46 million kilojoules exit the main tanks from evaporation. This could be increased to 1.47 billion kilojoules with evaporation from adding an industrial fan.



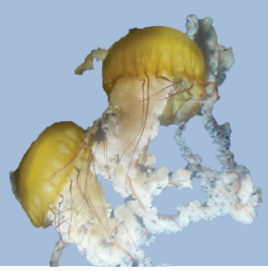
Results (20 year time horizon):
CO_2 reduction = 1,033,433 lbs, NPV = $193,589

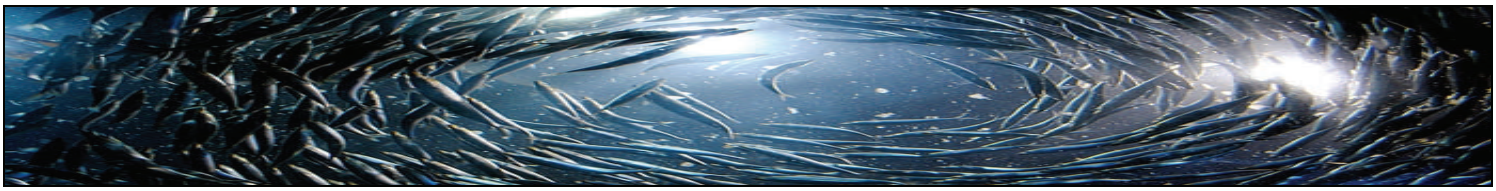
Additional Chiller

How it works: An additional main chiller would allow the aquarium to cool the water to temperatures that would be safe for the animals.

What we did: A second chiller will withdraw 17 billion kilojoules of heat from the water to reach the 14°C threshold that is safe for animals.

Results (20 year time horizon):
CO_2 reduction = 87,323,355 lbs,
NPV = -$18,635,742





Pumping

In general, a higher flow rate has a positive impact on animal health and water quality. AOTB uses a total of 35 pumps to move water through the life support systems, which represent 67% of the Aquarium's energy expenditures. The following improvement options were assessed:

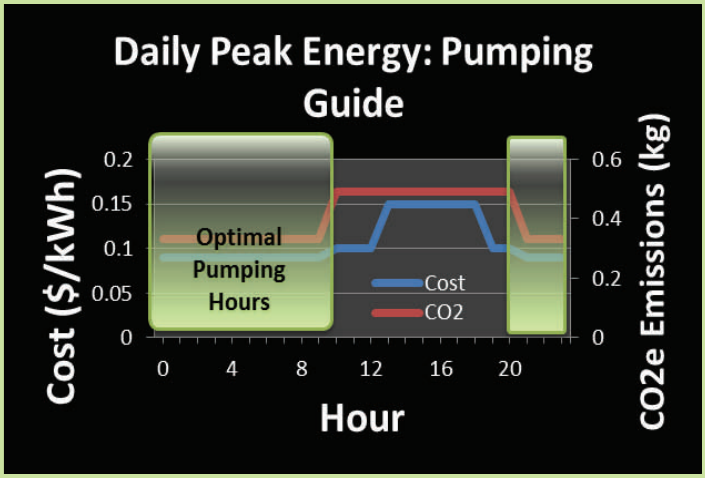
Demand Response Plan

How it works: The price of electricity and emissions of CO_2 increase when daily demand is highest.

What we did: The sea water pump operates for 14 hours per day on average. Savings can be realized by operating the pump exclusively during off-peak, or low demand, hours of the day.

Results (20 year time horizon):
CO_2 reduction = 501,180 lbs, NPV = $37,639

Motor replacements



How it works: Motors convert electrical energy into mechanical energy to spin a pump's impeller and push water. If a pump does not have enough horsepower to match the water pressure (what technicians call "head") in a system, the pump will operate less efficiently. Matching pump strength to system head will increase pump efficiency.

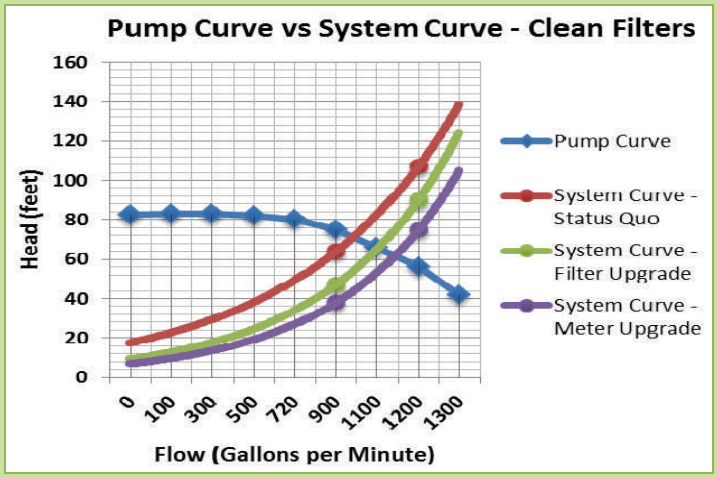
What we did: Many of the motors on the pumps operate at lower efficiencies. We recommended replacing 16 motors in total.

Results (20 year time horizon):
CO_2 reduction = 276,346 lbs, NPV = $48,623

Variable Frequency Drives (VFD)

How it works: A VFD adjusts the speed of the pump according to the head in the system. This saves energy by reducing the pumping power when the system permits rather than always running at full speed.

What we did: System head can be reduced from 75 feet to 69 feet by replacing media in the sand filters, and to 63 feet by replacing paddle flow meters (which measure water flow rate) with magnetic flow meters. VFDs can match pumping strength to head fluctuations in the system.



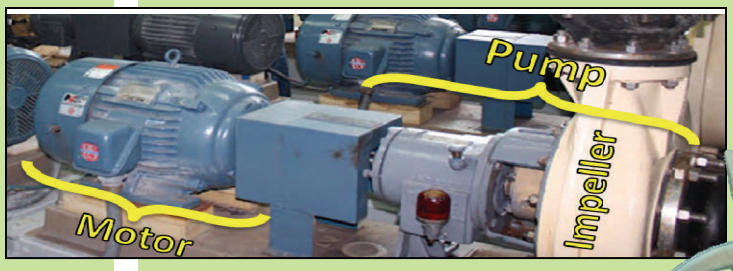
Results (20 year time horizon):
CO_2 reduction = 1,906,740 lbs, NPV = $328,489

Power Conditioners

How it works: Power conditioners improve the power factor of a motor by storing electricity and discharging it to the motor when power is needed.

What we did: An efficiency increase of 8% was assumed for the ten largest motors.

Results (20 year time horizon):
CO_2 reduction = 1,344,280lbs, NPV = $285,024



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Renewable Energy

CleanPowerSF

How it works: Beginning in mid-2012, the Aquarium will have the option to purchase electricity from one of two providers, PG&E and CleanPowerSF.

What we did: CleanPowerSF is the "greener" provider, with the goal of using 100% renewable energy sources, as compared to PG&E's 16% renewable energy portfolio. However, this will come at the cost of about 1.6 cents/kWh.

Results (20 year time horizon): CO2 reduction = 22,387,460 lbs, NPV = -$658,361

Recommendations

Our recommendations were compiled into three scenarios. **Scenario 1** is carbon-focused, with the goal of maximizing carbon emissions reduction. **Scenario 2** is animal-focused, with the goal of maximizing animal welfare in the most sustainable manner possible. Finally, **Scenario 3** is a balance between the two, with the goals of reducing carbon emissions, saving money, and improving animal welfare.

The scenarios were created with the intent of giving the aquarium the option to achieve the goals that they see fit. However, it is the recommendation of the master's group that the aquarium implement **Scenario 3.**

This will save $671,000 (NPV) and 3,967,510 lbs (CO_2), over the next 20 years.

Scenario 1 (Carbon Focused)

Goal: minimize AOTB's greenhouse gas emissions

Includes:

Water Cooling
1) Insulation
2) Fan

Pumping
3) Power Conditioners
4) Demand Response Plan
5) Motor Replacement

Other
6) CleanPowerSF

Scenario 2 (Animal Focused)

Goal: improve animal welfare the greenest way possible

Includes:

Water Cooling
1) Insulation
2) Additional Chiller
3) Fan

Pumping
4) Power Conditioners
5) Demand Response Plan
6) Motor Replacement
7) Variable Frequency Drive

Scenario 3 (Balanced)

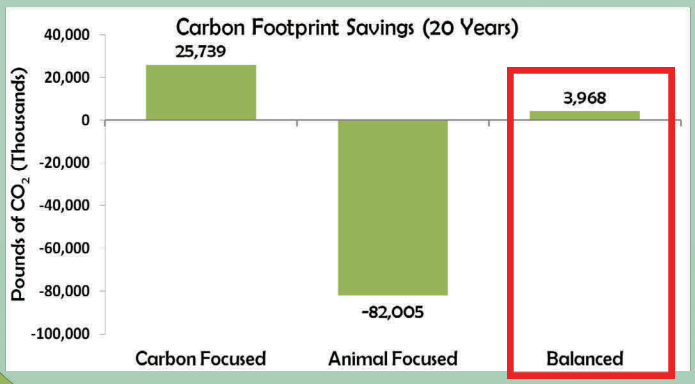
Goal: improve animal welfare and aquarium sustainability in a cost-effective manner

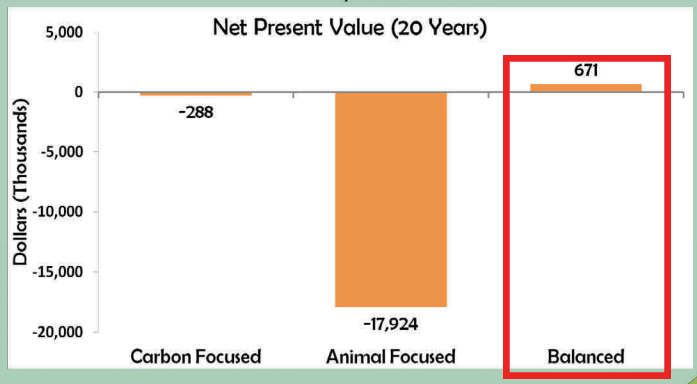
Includes:

Water Cooling
1) Fan

Pumping
2) Power Conditioners
3) Demand Response Plan
4) Motor Replacement
5) Variable Frequency Drive

Other
6) No Sensitive Rockfish





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