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Cool as a (sea) cucumber? Exploring public attitudes toward seawater air conditioning in Hawai‘i

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ABSTRACT

Seawater air conditioning (SWAC) has the potential to reduce the energy demand for air conditioning by 75–90%. This article reports the findings of a mail survey sent to residents of the Hawaiian island of O‘ahu investigating attitudes toward SWAC and opinions of installing a system in Waikīkī. Results show that while only 55% of O‘ahu residents were previously aware of SWAC, 62% supported its development in Waikīkī and just 7% opposed. Of those familiar with the technology, support rose to 69%. However, when compared to eight other low-carbon energy options, SWAC ranked second to last. Concern exists about the potential environmental impacts of SWAC, particularly with regard to reef damage and algae production. Logistic regression analysis shows no significant difference in the likelihood of a person supporting SWAC due to their sex or level of education; although age, political affiliation, and locality do affect the likelihood of support. Those who see tourism as very important to Hawai‘i and think SWAC will benefit the tourism industry are more likely to support, along with those who have a very positive opinion of renewable energy, and those who are familiar with the technology. In contrast, high-income O‘ahu residents are less likely to support SWAC.

1. Introduction

In tropical climates, air conditioning (AC) typically accounts for a significant percentage of the energy demand of hotels and other large buildings. In Hawai‘i, for example, it is estimated that 42% of the energy use from hotels and 34% from office buildings stems from AC requirements [1]. Globally, it has been estimated that one trillion kilowatt-hours of energy are required to satisfy our desires for cool indoor spaces [2] and demand is projected to increase throughout the coming century [3]. The vast majority of this increased demand will come from developing countries. Currently, the United States uses more energy for AC purposes than every other country in the world combined – a state of affairs that is unlikely to remain the case for long [4]. In an analysis of future air conditioning demand, Sivak (2013) ranked every country according to its person cooling degree days – a measure that multiplies a country's population by its cooling degree days[1] – in order to estimate potential future demand for cooling. Of the top 25 countries, 22 are developing nations, and rising global incomes, coupled with increasing temperatures, are likely to have a corresponding effect on the use of AC in these countries. If the use of air conditioning in India (which tops the list) ever matches that of the United States, its demand for cooling will be 14 times as great [4].

With this in mind, it is understandable that there is interest in finding less energy-intensive ways to cool buildings. Approaches to reducing global demand for AC range from rethinking urban planning and building design – for example by creating more open spaces, increasing the amount of shade, improving air flow, or reducing anthropogenic heat production [5] – to implementing technological advancements in AC systems, such as displacement ventilation, adsorption chillers, or desiccants [6–8]. In locations with access to a deep body of water, such as the ocean or a deep lake, one way of reducing the energy demand of AC is to harness the cooling properties of water. Depending on the location, and the source of the cold water, this process is known as seawater air conditioning, seawater district cooling, deep lake water cooling, or

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[1] Cooling degree days are calculated by subtracting 18 °C from the mean daily outdoor temperature of a region and summing the positive values over a set period of time. For example, a mean daily temperature of 25° would result in seven cooling degree days. Summing all of the cooling degree days over the course of a year provides an annual value which can be used to easily compare one region to another.

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lake-source cooling. The islands that make up the state of Hawai'i have access to such a cooling source. Presently, Hawai'i generates 88% of its electricity from fossil fuels and has dense population centers located within close proximity to cold ocean water (particularly on the island of O'ahu) – two factors that make seawater air conditioning (SWAC) an appealing alternative to traditional AC.

AC is not only energy intensive, but also expensive, due to the specific mix of fuel sources in Hawai'i. As Hawai'i has no fossil fuel resources of its own, the state must import all of the fuel it requires for power generation. In 2011, 73% of Hawai'i's electricity was generated from petroleum products, 15% from coal, and the remaining 12% from renewables [9]. This reliance on petroleum products results in Hawai'i having the highest electricity prices in the United States. In the year of our survey (2012), residential electricity rates in Hawai'i ranged from 35.1¢ per kilowatt-hour (kWh) on O'ahu to 46.6¢ per kWh on Lana'i; the U.S. average at the time was 11.9¢ per kWh.

In response to Hawai'i's reliance on imported energy, the Hawai'i Clean Energy Initiative, a partnership between the state and the U.S. Department of Energy, was established in 2008 with a goal of "transforming Hawai'i to a 70% clean energy economy by 2030" [10]. This transformation is to be achieved by a combination of increased renewable energy generation (40%) and improved energy efficiency (30%). As an energy displacement technology, SWAC would contribute to the state's energy efficiency target.

A SWAC project in the Waikīkī district, Honolulu's top tourist destination, is an especially attractive business proposition. The visitor industry requires year-round climate control and tourists typically use more electricity than locals. Nasseri et al. estimated that in 2007 the average visitor to Hawai'i used 1.5 times more electricity per day than the average resident [11]. By displacing electricity, district cooling offers significant benefits in terms of energy security and greenhouse gas emissions reductions, as well as reduced costs. Sustainable tourism benefits may also have marketing value. Yet, the initial development project would involve significant upfront investment and construction inconvenience. Moreover, given the tremendous value of the Waikīkī shore, even small impacts on surf, reef, beach, and water quality would have consequential impacts on the many users of the resource. Technical implementation is key to the success of Waikīkī SWAC.

It is against this backdrop that public attitudes toward SWAC are considered. Hawai'i provides an interesting case study for such an investigation for two reasons. First, SWAC is a viable option for Hawai'i, and second, past public opposition in the state to wind power, ferry transportation, and geothermal energy has proven to be an effective barrier to the implementation of otherwise sound business models. Unlike most of the United States, Hawai'i has a sizeable indigenous population[2] and, while the NIMBY (not in my backyard) effect cannot be discounted as a factor behind anti-development sentiment, there also exist deeper concerns about indigenous culture and the environment. For example, initial opposition to volcanic geothermal energy stemmed from a respect for the Hawaiian goddess Pele [12] and was tempered through involvement of indigenous leaders.

This article presents a survey analysis of O'ahu island residents concerning their knowledge and opinion of SWAC and other public issues related to energy, environment, education, and the economy. A key finding is that just over half of the population of O'ahu is familiar with SWAC, and those who are aware of the technology are significantly more disposed to support its implementation in Waikīkī. Thus, findings of this study inform potential project design and related educational efforts. The level of support seen for SWAC in this study (62% in favor among all respondents, 69% among those who were previously aware of the technology) is in line with past research into public support for marine energy. While other studies have focused on energy generation (primarily offshore wind and wave energy) our findings indicate that people are as likely to accept a marine energy displacement technology such as SWAC.

In addition to addressing a specific technology, this article also touches on a number of more general questions related to energy and society [13]. For example, the financial benefits of a SWAC project in Waikīkī are likely to only be realized by the project developer and the owners of the hotels and other large buildings who adopt the system. Most residents of O'ahu would not benefit financially from SWAC (unless they happened to live in a condominium that used the technology). However, SWAC also generates benefits to society, such as reductions in carbon dioxide emissions and freshwater use. Are these societal benefits high enough for people to support such a project – especially if it were to be subsidized with public funds? Secondly, how do people trade off the benefits of SWAC with potential local negative impacts? As will be seen below, while building a SWAC system does not necessarily cause damage to the local environment, depending on how the project is designed there is the possibility of reef degradation or algal blooms. Do the broader benefits of SWAC outweigh local impacts, or do local concerns trump global ones?

2. Background

Seawater air conditioning works by pumping cold (4–7 °C) seawater into a cooling station where, through a heat exchanger, it chills fresh water flowing in a separate closed loop. The slightly-warmed seawater is then returned to the source at a shallower depth and the newly-chilled fresh water is circulated through a district cooling system (Fig. 1).

A number of seawater or deep lake water cooling systems exist worldwide. In Hawai'i at the site where the basic technology for SWAC was invented, a small facility (rated at 30–50 tons of refrigeration) has been operating at the Natural Energy Laboratory of Hawai'i Authority (NELHA) since 1986,[3] and other systems exist in Bora Bora (450 tons), Toronto (58,000 tons), Stockholm (80,000 tons), and at Cornell University (20,000 tons). Lastly, a 25,000 ton system (different from the proposed Waikīkī system that is the focus of this study) is planned for downtown Honolulu with construction expected to be completed in 2017 [14].

Traditional air conditioning systems in large buildings have a number of components. Pipes circulate chilled water through the building, fans blow over the pipes to supply cool air to the rooms, and chillers and cooling towers chill the water that is circulated through the pipes. Chillers reduce the temperature of the water through the evaporation and condensation of a refrigerant. In the low-pressure environment of an evaporator, the refrigerant is converted into a gas, absorbing heat as it evaporates. The gas then enters a condenser where, under higher pressure, it is compressed back into a liquid state, heating up along the way. The excess heat from the liquid is transferred to a heat sink where it is expelled to the surrounding area. The newly cooled liquid refrigerant is then circulated back to the evaporator where the cycle begins again.

[2] According to the 2010 U.S. Census, 10% of Hawai'i's population identified themselves as Hawaiian or Other Pacific Islander and a further 16% classified themselves as part Hawaiian or Other Pacific Islander.

[3] Seawater air conditioning in Hawai'i actually dates back to 1983 when Arlo Fast, a University of Hawai'i Sea Grant-funded researcher, jury-rigged a makeshift seawater air conditioner while studying Pacific Northwest salmon at NELHA on the Big Island. With ready access to cold seawater for his research, Fast built Hawai'i's first functioning SWAC system out of an old truck radiator and household box fan [15]. In 1986, NELHA adopted SWAC in its main laboratory and has been operating the system ever since.