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# Ocean thermal energy resources in Colombia

Andrea Devis-Morales [a,c,*], Raúl A. Montoya-Sánchez [b,c,1], Andrés F. Osorio [a,1], Luis J. Otero-Díaz [c,d,2]

[a] Grupo de Oceanografía e Ingeniería Costera, OCEANICOS, Universidad Nacional, Medellín, Colombia
[b] Programa de Maestría en Ingeniería – Recursos Hidráulicos, Universidad Nacional, Medellín, Colombia
[c] Centro de Investigaciones Oceanográficas e Hidrográficas del Caribe, CIOH, Cartagena, Colombia
[d] Departamento de Física, Universidad del Norte, Barranquilla, Colombia

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ABSTRACT

Colombia's exclusive location surrounded by the warm tropical waters of the Caribbean Sea and the eastern equatorial Pacific Ocean make it a suitable region for ocean thermal energy conversion (OTEC). These are systems that can produce significant amounts of renewable electricity. From the assessment of the temperature gradient and the bathymetric, environmental and socio-economical characteristics, the maritime area around the island of San Andres (in the northwestern Caribbean Sea) was found to be ideal for an OTEC facility since sea surface temperature varies only slightly during annual and interannual timescales. The thermal difference encountered from the surface to a depth of 1000 m is always around 22°–24 °C and cold waters are available for intake at around 450–750 m, within a short horizontal distance from the coast (less than 2.5 km). At these depths, the 20 °C thermal gradient required for OTEC operations is achieved. Furthermore, winds, waves and surface currents around the island are of relatively weak intensity. Presently, energy sources based entirely on Diesel generators are inducing negative impacts on the sustainable development of the region and on the fragile marine ecosystem. An environmentally friendly 10 MW OTEC facility could be part of future energy and water management solutions for the island. It would cover nearly 50% of total electricity demands and provide important additional advantages such as chilled soil agriculture, aquaculture, freshwater, mariculture and seawater air conditioning.



## 1. Introduction

66% of Colombia's conventional power is generated by large hydroelectric plants and 32% is produced by thermoelectric generators that use coal, gas and other fossil fuels. The current capacity of renewable energy resources (2% of total) is produced by photovoltaic solar systems, small hydroelectric stations and a wind park located in La Guajira in northern Colombia [1]. Based on the current economic growth rate, Colombia's electrical energy demand is increasing by around 3.6% per year. However, this value is considered abnormally low and is related to the recent global financial crisis that impacted most Latin-American socio–economic activities. The 2008 report from the Colombian Association of Electrical Energy Generators (ACOLGEN) estimated that if the economic growth rate normalizes in the near future, energy demand could increase by 4.7% per year (high scenario). In this case, by 2018 it would be necessary to build a new 450 MW plant every year in order to meet demands [2]. The depletion of fossil fuels, the impact of natural climatic events such as El Niño/La Niña on water resources and Colombia's commitment to comprehensively address the implications of climate change are all important factors. They have led to investment in the development and application of alternative technologies to produce electricity, based on other available renewable energy sources, to be considered.

Colombia's maritime area (540,876 $km^2$ in the Caribbean Sea and 339,500 $km^2$ in the eastern equatorial Pacific) and long coastline (2900 km) encourage the search for new ways to take advantage of these vast reservoirs of untapped energy. In 2010–2011 the scientific community, sponsored by local universities, maritime authorities, and the EPM Energy Company, initiated

* Corresponding author. Universidad Nacional, Facultad de Minas, Bloque M2, Carrera 80, No 65-223, Núcleo Robledo, Medellín, Colombia. Tel.: +57 4 2304226, +57 3 105130728 (mobile).
*E-mail addresses:* adevismo@hotmail.com, admoceanologa@gmail.com (A. Devis-Morales), raul.a.montoya.s@gmail.com (R.A. Montoya-Sánchez), afosorioar@unal.edu.co (A.F. Osorio), ljotero@uninorte.edu.co (L.J. Otero-Díaz).
1 Universidad Nacional, Facultad de Minas, Bloque M2, Carrera 80 No 65-223, Núcleo Robledo, Medellín, Colombia.
2 Universidad del Norte, Departamento de Física, Km. 5 Vía Puerto Colombia, Barranquilla, Colombia.

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the first national attempt to evaluate ocean energy resources. These included waves, tides, currents and thermal and saline gradients in both the Caribbean and Pacific basins. From this assessment it was determined that the exclusive location of Colombia's tropical marine waters (Fig. 1) was key to the future generation of electricity by means of the large upper ocean temperature differences encountered year-round [3].

This type of renewable energy, called ocean thermal energy conversion (OTEC) was first discovered in principle in 1881, by Jacques Arsene d'Arsonval, a French physicist [4,5]. With OTEC technology, the temperature gradient from the ocean surface to deep waters (~1000 m depth) can be used to convert heat energy into electricity. It functions best when there is a temperature difference of at least 20 °C. OTEC produces electricity from the natural thermal gradient of the ocean, using the solar heat stored in warm surface waters to drive hydraulic or vapor turbines [6]. After d'Arsonval's discovery, it was proven experimentally by the French professors Claude and Boucherat in 1926. Since then OTEC has been studied for its practical application for nearly 80 years. In the past the technique was rejected as impractical since it could only generate relatively small amounts of electricity. However, experts now consider it economically viable to generate electricity with today's technology in tropical zones where the ocean surface temperature does not fall in winter [7].

The most commonly used heat cycle for OTEC is the Rankine cycle, which uses a low-pressure turbine. Systems may be closed-cycle, open-cycle (OC) and hybrid. Closed-cycle engines use working fluids with a low boiling point, typically refrigerants such as ammonia, to power a turbine to generate electricity. Warm surface seawater is pumped through a heat exchanger to vaporize the fluid. The expanding vapor then turns the turbo-generator. Cold water, pumped through a second heat exchanger, condenses the vapor into a liquid, which is then recycled through the system. Open-cycle engines use vapor from the seawater itself as the working fluid. A small OC-OTEC plant can produce from 1 MW to 10 MW of electricity and at least 1700 $m^3$ to 3500 $m^3$ of desalinated water per day. Such quantities could cover the needs of developing communities with populations ranging from 4500 to 100,000 [8].

OTEC plants can either be built onshore or on offshore floating platforms. The onshore type require long intake pipes for pumping seawater to the land, high initial construction costs, large amounts of energy to operate the pumps, could be limited by the availability of the thermal resource near the coast and could enhance environmental impacts. However, these plants are maintained and repaired easily and provide water for multiple purposes, such as potable (desalinated) water, mariculture and air conditioning and refrigeration systems (seawater air conditioning, SWAC), making them a promising alternative, e.g. on small Caribbean islands. The floating platforms can be larger and do not require the use of valuable coastal land. However, these plants incur the added expense of transporting energy to the shore and it is also necessary

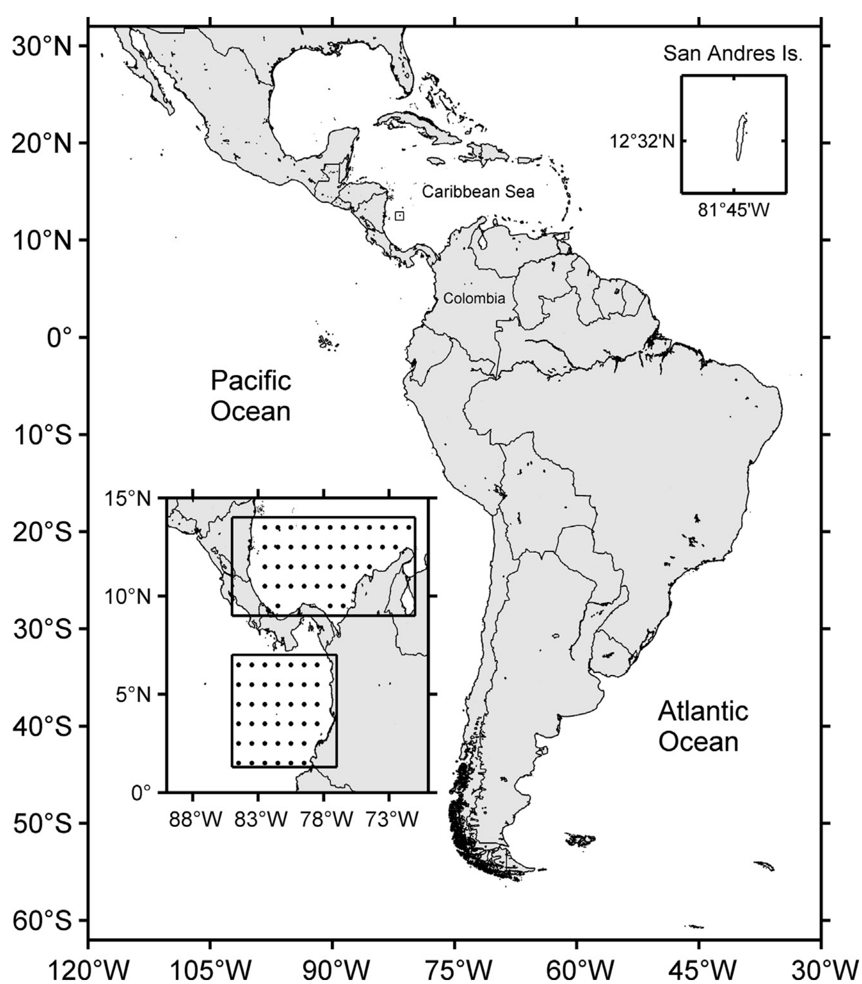


**Fig. 1.** Map of Colombia maritime study area. A detailed map (bottom left) shows the location of stations with WOA09 temperature data. San Andres Island, located in the western Caribbean Sea (small box) is illustrated in the upper right corner of the regional map.