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Assessment of the marine power potential in Colombia

A.F. Osorio [a], Santiago Ortega [b], Santiago Arango-Aramburo [c,*]

[a] Grupo de Investigación en Oceanografía e Ingeniería Costera (OCEANICOS), Faculty of Mines Universidad Nacional de Colombia, Sede Medellín Carrera 80 # 65–223, Bloque M2, Medellín, Colombia

[b] Grupo de Investigación en Oceanografía e Ingeniería Costera (OCEANICOS) Universidad Nacional de Colombia, Sede Medellín Escuela de Ingeniería de Antioquia Envigado, Medellín, Colombia

[c] Decision Sciences Group Faculty of Mines Universidad Nacional de Colombia, Carrera 80 # 65-223, Bloque M8a, Medellin, Colombia

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ABSTRACT

In this paper, we estimate the potential marine energy available from different types of resources in Colombia: waves, tides, currents, salinity gradients and thermal gradients, focussing on specific locations. The main constraint on this analysis is the lack of long-term marine instrumentation and data. In order to overcome this difficulty, we use oceanic numerical modelling with data from reanalysis models, climatic data from remote sensors, and primary data from existing instrumentation and fieldwork. The models were calibrated and run to calculate—based on existing marine systems—the potential nationwide marine power resources, on different time and spatial scales, for both the Colombian Caribbean and Pacific coasts. For each marine resource, we first explain the method used to assess the power potential; then we present the potential marine energy result. Further, we carry out a policy analysis where we discuss not only the power potential but also the barriers (mainly cost) faced by marine energy. Given the potentials found by earlier studies, these results define for Colombia, and also for Central and South America generally, the road map for future pre-feasibility analysis, taking into account the energy demands of the populations, existing technologies, and the environmental, social and geographical characteristics of the regions.

Contents

* Corresponding author. Tel.: + 57 314 8558854.
E-mail addresses: afosorioar@unal.edu.co (A.F. Osorio), santiagortega@gmail.com (S. Ortega), saarango@unal.edu.co (S. Arango-Aramburo).

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1. Introduction

There has been an increasing focus on global warming in recent decades: in particular, on the emissions of CO_2 and other greenhouse gases, and in general on the impact that human activity has on the climate and the problems this might create. There exists a series of agreements in which the international community has agreed to reduce emissions, using different strategies. Thus, there is a general consensus about the need to reduce emissions; but there is less agreement on how it should be done, who should do it, and what it will cost. To begin with, the Kyoto Protocol framework promotes the implementation of policies for research and development of renewable energy sources, carbon sequestration technologies and innovative environmentally-friendly technologies [1]. A revision of this agreement took place at the World Summit on Sustainable Development in Johannesburg in 2002, which encouraged a greater share of renewable energy in energy supplies [2]. Despite the lack of concrete targets for renewable energy sources [3], the revision influenced energy policy in this respect.

Electricity generation is one of the major contributors to GHG emissions, or more specifically it is the use of thermal generation capacity based on oil, coal and gas. There are other generation technologies, which do not contribute to emissions, such as nuclear, as well as alternative energy sources such as wind, solar, hydro plants (both large and small-scale plants) and marine energy. For a country trying to reduce emissions, the use of renewable resources for generation should ideally be the first choice, both for capacity expansion and when replacing existing capacity. There are well-known environmental problems relating to nuclear plants (such as radioactive waste) and large-scale hydro plants (local environmental problems with dams), which we do not deal with in this paper. Beyond those alternatives, with their pros and cons, we focus here on the potential of marine energy in Colombia.

In this paper, we explore the potential marine energy available from a range of different sources: waves, tides, salinity gradients and thermal gradients. This analysis will provide initial estimations of the potential in specific areas. One of the main restrictions for analysing the marine power potential in the country is the lack of long-term marine instrumentation necessary to make an appropriate and sound characterisation of oceanographic phenomena. To overcome this difficulty, a path using oceanic numerical modelling was followed. The simulations used inputs from reanalysis models, and climatic data from remote sensors, to model different oceanographic phenomena and to generate synthetic information. The models were calibrated using data from existing instrumentation and fieldwork. After these processes the models were run to calculate the existing nationwide resource on different time and spatial scales. Once there is long-term and reasonably reliable oceanographic information, an estimate of the power potential is calculated. The methodologies were applied to evaluate the power for each resource in several areas on the Colombian Caribbean and Pacific coasts.

The rest of the paper is organised as follows. The next four sections present assessments of the power potentials for waves, tides, thermal gradients and currents, and saline gradients. For each power source we first explain the method of assessing the potential; then, we present the result. Section 6 presents policy analysis, where we discuss not only the power potential but also the barriers—mainly cost—faced by marine energy; Section 7 provides final comments.

2. Assessment of power potential: waves

2.1. Method

We use a simulation model to mimic wave behaviour over time and quantify the wave power potential. The model chosen to simulate waves was the SWAN – Simulating WAves Nearshore model [4], which is a third-generation wave model developed at the Delft University of Technology in the Netherlands. There is a wide variety of wave models, such as WAM and WaveWatchIII; however, we have chosen SWAN because of its ability to propagate waves on different scales, and because simulation results can be downscaled using nested runs [5].

Inputs for the modelling include bathymetries and 10 m-high wind data. The bathymetries were constructed using information from the ETOPO1, a 1 arc-minute global relief model of the Earth's surface, developed by the NOAA [6], and from the “Sistema de Modelado Costero” (SMC) Coastal Modelling System [7], a programme developed by the University of Cantabria that contains a database of the bathymetries of the Colombian maritime territories.

The Caribbean Sea can be considered a sheltered sea (see Fig. 1), as the Antilles stop most of the wave fluxes from the North Atlantic. This means that the waves present in the Colombian Caribbean are generated by the trade winds inside the Caribbean Basin [8]. Under this considerations, contour data was not used for the simulations. The wind data was taken from by North American Regional Reanalysis – NARR [9] made by the National Center for Environmental Prediction, NCEP, and the National Center for Atmospheric Research, NCAR. Thirty-two years of 10 m-high wind data, at 3-h intervals (i.e. eight times daily) is presented in a grid with data points approximately 0.25° apart. The simulations covered a region between latitude 6–22°N and longitude 60–90°W. Results are downscaled to different grids with finer resolution and smaller domains, until a 3 arc-minute resolution is reached. The calibrations and validation of the SWAN model for this Caribbean region have been previously tested [5].

Wind data from the NARR is available only in a fraction of the Pacific Ocean; therefore, the winds for simulating waves in the Colombian Pacific are taken from the *Global Reanalysis 1 Project,* (NCEP/NCAR). Data from this project is presented every 6 h (i.e. four times daily) for a period of 60 years. There is data for a worldwide grid with lower resolution, where data points are approximately 2.5° apart [10].

The Pacific, having swell waves with long periods, is unlike the sheltered Caribbean Sea. Modelling the totality of the Pacific Ocean is a complex exercise that was previously carried out by the Environmental Hydraulics Institute *IH Cantabria* for the *GOW Global Ocean Waves 2.1* Project [11]. *IH Cantabria* modelled waves worldwide over a $1° \times 1°$ grid, using the NCEP/NCAR data. Wave data from this project was used as a contour map for modelling the Pacific Ocean. As in the Caribbean Sea, results were downscaled until a 3 arc-minute resolution was reached.