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METHOD FOR USE OF WAVE ENERGY FOR CAPTURE OF ATMOSPHERIC CO2 COUPLED WITH ELECTRICITY PRODUCTION

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ABSTRACT

Here I propose that a simple system, using wave power for generation of high gas pressures, could be employed to condense CO_2 out of the atmospheric air for subsequent sequestration or industrial use. Importantly, such a method can be coupled with electricity production by employing the generated CO_2 -free/reduced high-pressure air to drive a turbine/generator. Coupling CO_2 capture with electricity production could provide the financial incentive for reducing the atmospheric CO_2 concentration.

INTRODUCTION

With an increasing concentration of carbon dioxide (CO₂) in the atmosphere leading to global warming (Stocker, 2013), one of the pressing questions is how to reduce the CO₂ level again. Several different approaches have been proposed such as using plants, algae and bacteria to fix CO₂ during growth for subsequent storage (Gibbard, et al., 2005; Malhi, et al., 2005; Bala, et al., 2007; Kumar, et al., 2011; SK, et al., 2013; Moreira and Pires, 2015) the use of chemical reactions to capture the CO₂ out of the air, such as the use of Ca(OH), mediated capture to form Calcite (CaCO₃) (Yang, et al., 2008; Manovic and Anthony, 2010) as well as, solvents (Aronu, et al., 2009). However, one unexploited way of carbon removal is to use wave energy to compress and condense CO₂ from atmospheric air for subsequent sequestration; a method that also lends itself to associated electricity production.

Currently, wave energy is one of the most underutilized renewable energy sources, indeed the World Energy Council has estimated that wave energy if fully exploited could generate 29,500 TWh a year, which corresponds to almost one and a half times the world's current total electricity production World Energy Council, 2016; Gunn and Stock-Williams, 2012). However, the electricity generating wave systems installed worldwide, only have a total

capacity of 0.5 GW. One of the pressing problems has been the expense of electricity generated using such systems; the best systems in the UK generate electricity at a cost of 7.5 cents per KWh, while generating electricity from a natural-gas fired plant costs about 3 cents per KWh (Ocean Energy Council, 2017). Numerous approaches have been proposed and developed for energy production using wave energy (Falnes, 2007; Falcao, 2010). Many systems use the movements of floating or submerged devices to generate electricity. Some of these devices, fixed to the seafloor or the shore, utilize rocking movements of the equipment driven by passing waves, to drive generators; the main types being attenuators, point absorbers, oscillating wave surge converters, oscillating wave column absorbers and submerged pressure differential absorbers (Falnes, 2007; Falcao, 2010). Importantly, such rocking movements of these devices can easily be used for the compression of atmospheric air, for example using simple pistons and cylinders, for the condensation of CO₂ in combination with electricity production (Fig. 1). As CO₂ is the densest molecule of the major components of atmospheric air, it is the first gas to condense when the pressure is raised to above 34.4 Atm at 0°C or 72.8 Atm at 31.1°C (National Institute of Standards and Technology, 2016). Thus, if an array of such wave devices acts to compress the atmospheric air to a pressure above this critical pressure, by pumping



Fig. 1 Schematic diagram of the proposed method for CO₂ removal and power generation. The wave generated rocking movements are used to compress air. One way to archive this is with pistons (Gray squares) and cylinders (open rectangular shapes). Compression could as shown involve serially connected cylinders (of decreasing volumes, not shown) to produce the pressures needed. The compressed air is collected in a central main tank 6 (ellipse) where the liquefied CO_2/H_2O accumulate at the bottom for later removal (vertical arrow). The CO₂-free air above the liquefied CO₂ in the main tank can be used (horizontal arrow right) for driving a turbine/generator for electricity production. The expansion of the air in the turbine will have a cooling effect that can be harvested (horizontal arrow left) to maintain the main tank's temperature below the surroundings.

the air through high-pressure resistant tubes to a central tank, also holding the air above the critical pressure, then liquid CO₂ will accumulate in the tank with time. The condensed CO₂ together with condensed water can be removed when needed and either used for industrial applications (Hills, et al., 2016; ElMekawy, et al., 2016) or sequestered in the underground (White, et al., 2003). It should be noted that an additional collection tank potentially could be installed before the last compression step, such that condensed water can be collected before the condensation of CO₂ during the final compression. Furthermore, the remaining CO_2 free (or with a significantly reduced CO, content) pressurized gasses can then (at intervals) be released to drive a gas turbine/generator for electricity production. Release and expansion of the gasses in the turbine will have a cooling effect, which can be employed to maintain the temperature of the central storage tank below the temperature of the surrounding environment. Such cooling will reduce the pressure required to maintain the CO₂ liquid. Additional advantages of the proposed method of using compressed air for electricity generation using waves are: 1) electricitygeneration can take place at a wider range of weather conditions; even when waves are less energetic; conditions that systems where the generator is driven directly by the wave mediated movements have problems doing; 2) the intermittent power input of the waves can be converted into a more constant electric power out-put; 3) the wave-energy capturing systems would be easily scalable and modifiable; the number or type of wave-energy-capturing subdevices can vary between installation's dependent on the specific location's waves' size and frequencies; 4) the technologies needed to implement the proposed type of carbon-capture are all available (gas turbines/ storage tanks, wave energy capture devices); 5) waveenergy capturing systems will be cheaper to produce as only one generator\storage tank can be used for many wave-energy capture sub-devices, potentially making wave energy a competitive source of energy. Finally, if such a wave mediated compression system is fed exhaust gasses from power-plants, it could be used, not for energy production, but for generating the pressures needed for condensing CO₂ in the exhaust, as well as, for pumping the liquefied CO₂ gas into the seabed for sequestration. In conclusion, by coupling CO₂ capture with energy production, the expense of reducing atmospheric CO₂ can be kept to the minimum, and might provide a financial incentive. Indeed, companies or countries utilizing the propose carbon-capture system, would be able sell carbon credits, or have increased their available carbon credits.

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