The Neowave wave energy converter: Technical and financial approach.

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I. Introduction

The entire world has today an increase in the energy demand, due to its population growth and a wide use of electrical and electronic devices.
But the current electricity generation still depends on fossil fuels in some world areas, affecting the environment and the life's health on earth.

Background on general needs

In the present, the use of clean energy resources through new or advanced techniques is very important to achieve the United Nations' Sustainability Development Goals (UNs' SDGs) and a global objective to a 100% carbon-free electricity.

But some developing countries do not have technological or financial resources to get imported solutions from developed countries. Every location has specific needs and the new technologies must be adaptable for installation aspects, affordable maintenance and control labors, parts change and local work force.

One of the ways to get clean electricity but no yet widely used, is the oceans wave energy. Waves have a theoretical potential energy at all world's water surface of 29.000 TWh/year (same global demand for electricity in 2019). At practical terms, a 2.900 TWh/year would be common closer to coasts. If we think about storage, waves act like energy reservoirs charged by the sun and the wind, which can travel for kilometers with virtually no loss of energy. Waves are more predictable and consistent compared with solar and wind energy. Waves are mainly found between tropics and the polar circles (30° - 60° latitudes) and are optimal in offshore waters with 40 meters deep [1].

Wave energy presents a multi-layered challenge due to complexities in power production and balances that must be achieved. That is why worldwide devices continue with their development processes but with high cost and complexity designs.

The success for a Wave Energy Converter (WEC) deployment, is a combination of three main pillars: Resource, Device's technology and Finances [2] (see Fig. 1).

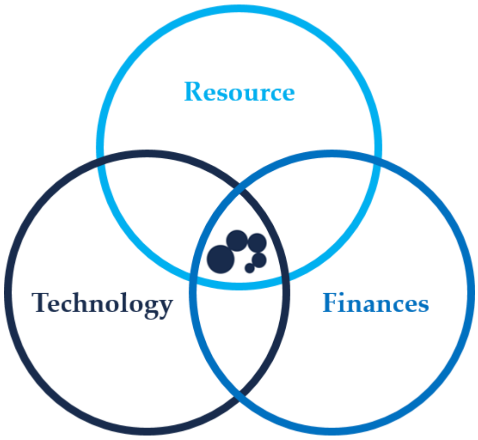

Fig. 1. Principles of balance for the development of any renewable energy technology. Neowave Energy is looking for all.

Background on technical problem be addressed

Rotary or linear electromagnetic generators use high speed to create electricity. Waves' movement is slow and forces to use mechanisms to increase the kinetic energy from the potential energy.

Gears, gear racks, cams, rods, pulleys or oils are used in actual technologies for power transmission and generators' speed increase, but this requires more maintenance labor, failures and costs.
Current wave energy projects use complex technologies, special parts and new manufacturing processes that are not available in some regions, isolated communities or developing countries, this increases the initial project's starting time, its investment and the future CapEx for the LCoE.

Floating non-standard structures use rigid volumetric geometries that need extra space to storage and expensive logistics with no stackable options, particularly in remote zones.

Waves are reasonably predictable. The expected flux of wave energy is known, but even a forecast longer than 7 days is not reliable.

II. Methods

Small scaled model justification

Colombia is a developing country with a volatile economy and limited access to imported new technologies. This is the justification for the use of local resources and the search for much simpler, more scalable and affordable solutions.

During the April 2020 quarantine, generated by the Covid-19, the availability of materials, tools, accessories and external services was limited, which is how the manufacture of a first manually operated model had to be done with very few resources, available at home, prior to the validation of the technical calculations and the elaboration of a functional model on a small scale.

After validating the technical calculations through the manually operated model, the design of a functional model on a small scale (1:30) was justified and the creation of a business concept that included analysis for: Market, finances, logistics, suppliers, materials, manufacturing processes, environmental and social impacts and branding, tasks that would take about 8 months to be completed.

The technical design of the model (and of the general device) followed the needs of the local market and the previously explained technical challenges.

LCoE formula

To calculate the Levelized Cost of Energy - LCoE, different expressions are used and include weighted iterative processes according to each year of the life time of the device, the above to take into account temporary changes in cost of living or material prices.

But for this article, the simplified form mentioned by the National Renewable Energy Laboratory - NREL [3] is used. This formula (1) can be used to calculate the cost of energy in the first year or in a specific future year:

$$LCoE = \frac{FR * IC + LRC + O\&M + Others}{AEP} \quad (1)$$

The different components of the formula (1) will be described in the Table I, as follows:

TABLE I
COMPONENTS OF SIMPLIFIED LCOE FORMULA VERSION.

Symbol	EQUIVALENCE	Unit
LCoE	Levelized Cost of Energy	$/MWh
FR	Financing Rate	%
IC	Initial Capital (CapEx)	$
LRC	Levelized Replacement Costs, annual	$
O&M	Operations & Maintenance Costs, annual	$
AEP	Annual Energy Production	MWh
Others	Taxes, place rents, etc.	$

III. Results

Small scaled model fabrication

In January 2021, when the markets and society had already reopened their activities, the manufacturing of the small scale functional model began, through traditional and affordable manufacturing processes in developed or developing markets, such as:

- Cutting.
- Turning.
- Welding.
- Adhesives and sealants application.
- Routing.
- Drilling.
- 3D printing.
- Others.

This activity culminated in March 2021 through a functional small scale model (Fig. 2) and the validation of the concept -TRL 3.

Fig. 2. Small scale functional model, and water level change mechanism after concluding the home-made tests.

After the TRL 3 validation through the small scale model, two Remotely Operated Systems (ROS) for maintenance (Lubrication and parts change) and control (Wave energy density adaptation and device's turn-off) were designed, looking for future cost reducing and LCoE competitiveness.

First year LCoE calculation

To facilitate the calculations and carry out different iterations based on the costs of the components, the services required by qualified personnel, and macroeconomic conditions of the place, an interface was modelled in a spreadsheet.

From it, the different components that constitute the LCoE, were plotted in Fig. 3 and interpreted in Table II, using practical and theoretical field conditions and costs of Neowave's parts and services.

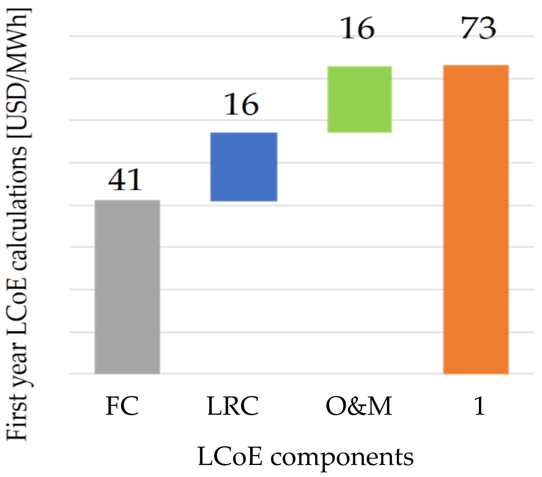

Fig. 3. General components of the LCoE calculations, based in the Neowave's technology at real and theoretical conditions.

Through the modelled interface, eight aspects about technical, natural resources and financial topics that impact in the costs of generated energy, were considered to create pathways for LCoE reductions.

Each aspect was varied in the interface, one by one, obtaining an individual cost reduction and each new reduction was accumulated with the previous ones to obtain the projected LCoE potential reduction.

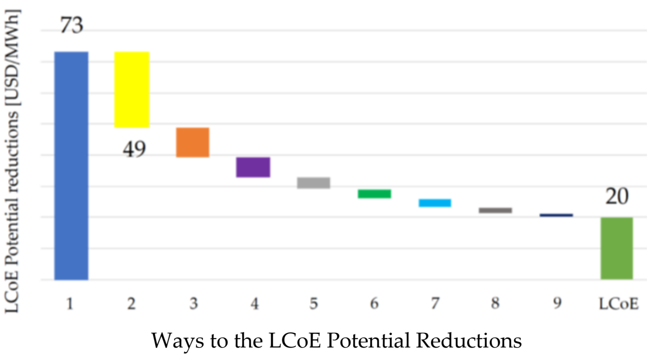

Fig. 4. Ways to the LCoE Potential Reductions.

The different pathways analysed by Neowave that will help for the LCoE potential reductions, were represented in Fig. 4 and interpreted in Table II.

TABLE II
COMPONENTS OF LCOE CALCULATIONS AND POTENTIAL REDUCTIONS

Symb.	Equivalence	Unit
FC	Financing Costs	
LRC	Levelized Replacement costs, annual	
O&M	Operations & Maintenance costs, annual	
1	LCoE reference	
2	Higher site's capacity factor.	
3	Lower Financing Rate.	
4	Device's scale increasing.	$/MWh
5	Hybrid with PV solar modules.	
6	Device's higher efficiency.	
7	Lower O&M costs.	
8	Own tubulars fabrication and own vessel	
9	Device's higher time of life.	
LCoE	Projected LCoE potential reduction	

IV. DISCUSSION & CONCLUSION

Neowave is a wave energy converter, point absorber type, based on fluid dynamics and energy conservation principles.

This scalable design is conformed with basic, standard, and commercial parts, the manufacturing and assembly are simple and it has a stackable structure.

The full-scale design has a 300KW capacity for a 6 meters high and 10 seconds period waves.

A remotely operated maintenance system was designed to reduce operation costs, fewer visits to the installation location, and for extending its useful life. A remotely operated control system was designed to device's adaptation to energy density changes, turn-off in storms, and harmonic movement with the waves. Two patent-pending processes are running for those systems.

A functional 1:30 size scale prototype was manufactured and the proof of concept was validated in a water level change mechanism, getting a TRL 3.

Financial analysis shows profitability and potential reductions for its LCoE.

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