

## Index - Final Report

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## 1. Final report

The final report must be prepared in English. Please fill in the following sections of the template.

### 1.1 Project details

<b>Project title</b>	The COE tool for WECs – Improvement and Dissemination
<b>Project identification</b>	2013-1-12135
<b>Name of the programme which has funded the project</b>  (ForskVE, ForskNG or ForskEL)	ForskEL
<b>Name and address of the enterprises/institution responsible for the project</b>	Aalborg University Department of Civil Engineering Sohngaardholmsvej 57, Dk-9000, Aalborg
<b>CVR</b> (central business register)	29102384
<b>Date for submission</b>	09-04-2014

### 1.2 Executive summary

Consulting Engineer Julia F. Chozas (contact person at [coe@juliafchozas.com](mailto:coe@juliafchozas.com)) together with Aalborg University and Energinet.dk have released a freely available online spreadsheet to evaluate the Levelised Cost of Energy (LCOE) for wave energy projects. The open-access tool calculates the LCOE based on the power production of a Wave Energy Converter (WEC) at a particular location. Production data may derive from laboratory testing, numerical modelling or from sea trials.

The scope of the COE Calculation Tool is to estimate the performance, costs and economic feasibility of the demonstration machines that are currently being developed.

The tool has been developed as a transparent and simple model that evaluates the WEC's economic feasibility in a range of locations while scaling the WEC's features to the selected site.

The aims of the COE calculation spreadsheet are as follows:

- Ensure consistent and transparent calculation methods.
- Provide a framework for performing COE analyses.
- Provide a tool for simple scaling of a machine according to different wave climates.

The COE Calculation Tool has the following characteristics:

- It is an open-access economic calculation tool.
- It uses broadly-known software: Excel.
- It includes default values for efficiencies and prices.
- It is simple and transparent: it promotes the understanding of calculation steps and results.
- It focuses on power production values instead of on installed capacity.
- It evaluates the COE in a range of locations.
- It encounters the unique feature of scaling the WEC according to locations.
- It focuses on input values rather on the outputs: it is conceived as an exercise for WEC developers.
- It is complemented by a user guide (the present document) and a quick-start user guide, where assumptions, input and output values are detailed.

The user of the COE Tool must note that he needs to hand in documentation that proves all input values for the tool whenever using the COE Tool.

#### *Why the Cost of Energy and the creation of a COE Calculation Tool?*

The NPV (Net Present Value) along with the COE are the two superior values to evaluate the economics of WECs. Particularly, the COE is useful when the support mechanism i.e. the feed-in tariff, is unknown or uncertain.

Therefore, the COE has been widely used as a driving factor to select technical alternatives, as well as to answer the question “which WEC is the best” or even “which form of electricity generation is the best”.

For example, the COE has been the decision parameter to access both public and private funding i.e. bank loans. Also, in the NER300 project of the European Commission (EC) awards were based on the COE value of the WECs applying.

There are however many fictions around COE calculations. Due to this lack of transparency in the calculations, there have been different initiatives to homogenise the COE calculations, and that has also been the goal of this project – to homogenise the COE Calculation in one transparent and simple spreadsheet.

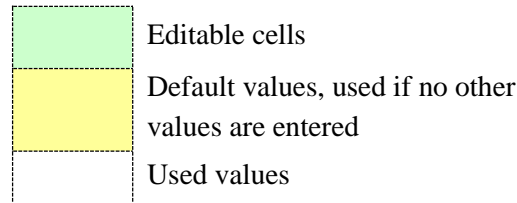
Additionally, the present COE Calculation Tool allows for sensitivity analysis. The current LCOE of wave energy converters is too high to be considered economic attractive with other sectors. As a result, there is a current and future need to decrease this value (which justifies the need for an R&D roadmap). This COE Tool may give hints of the areas where R&D is needed.

Ultimately, investor’s decisions are based on the economic performance of the technology, so an understanding of the economic implications for a specified WEC is always required, even if carried out at a very preliminary level.

It is therefore suggested to use the COE Calculation Tool and carry out an economic assessment of the technology at all the different stages of the development, especially at initial development stages where data might be available only from laboratory tests.

*About the COE Calculation Tool*

The spreadsheet is locked in order to protect the formulas and the tool structure. The colour codes in the cells are as follows:



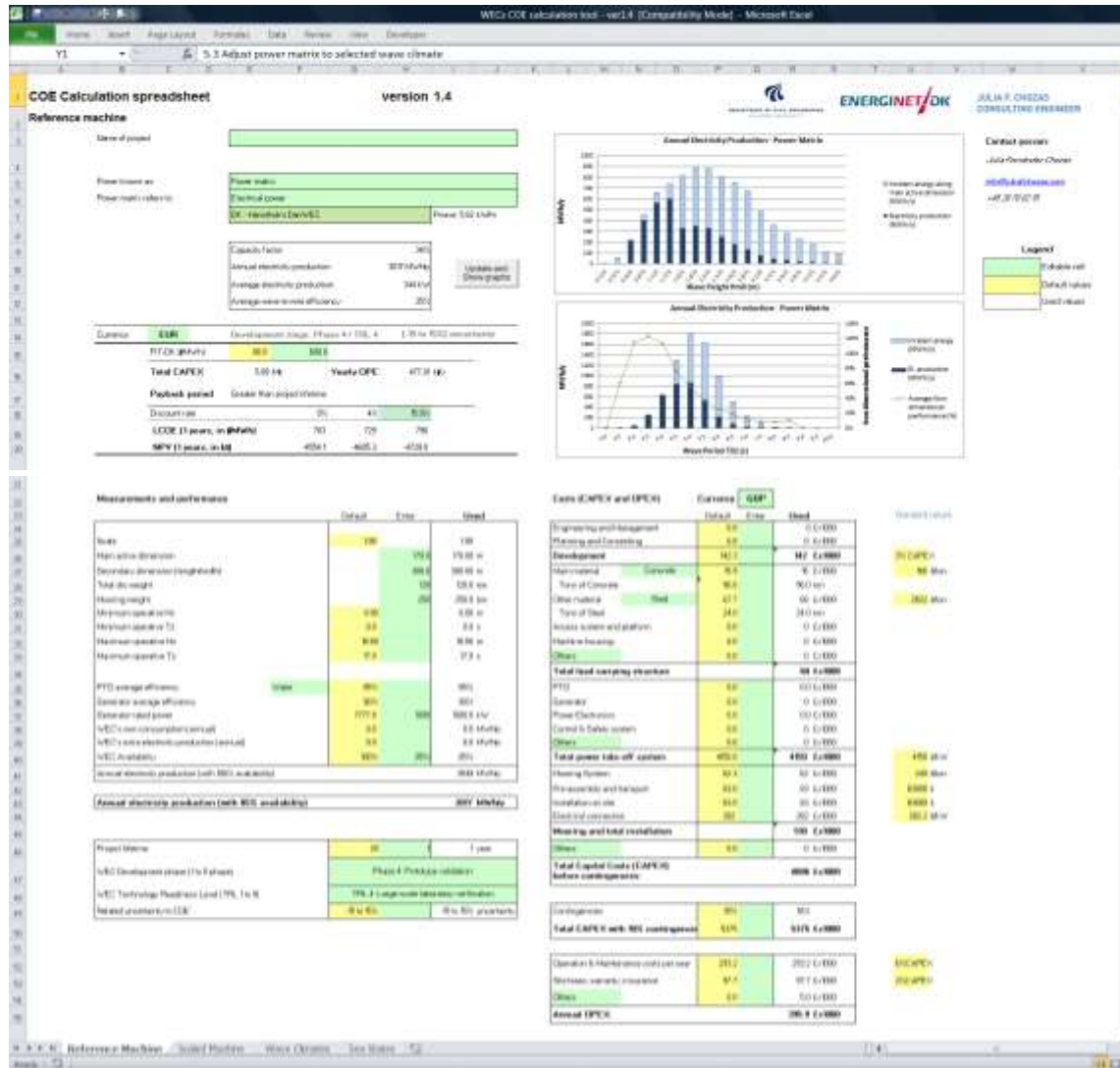
Thus, the green colour cells overwrite the values in the yellow cells.

The spreadsheet is based on a reference machine and gives the opportunity to calculate the scaled equipment and the costs associated to the reference and the scaled machines. The reference machine can be freely set.

In order to analyse the output values from the spreadsheet and, if suitable, be able to compare results among WECs and locations, the user must specify the assumptions behind all input data and include information about the WEC's development stage.

To which extent the individual parameters have to be documented depends on how far the WEC is developed.

The values used in the calculations are shown under *used*.



Front-end of the COE Calculation Tool (numbers shown are not inspired by any WEC)

### 1.3 Project results

The main result of the project has been the development of a well-functioning and validated Cost of Energy Calculation tool for the economic assessment of Wave Energy Converters. Along with the spreadsheet, the project has created a comprehensive User Guide (about 55 pages) and a Quick-Start User Guide (5-page document).

The Excel sheet and the two guides can be directly downloaded from three different websites:

- Energinet.dk website:  
<http://energinet.dk/DA/KLIMA-OG-MILJOE/Energi-og-klima/Forskning-i-vedvarende-energi/Sider/Boelgekraft.aspx>
- Aalborg University website:

<http://vbn.aau.dk/en/publications/user-guide--coe-calculation-tool-for-wave-energy-converters%2878b135d9-ea66-43f8-959f-c799dc4df1a9%29.html>

- Julia F. Chozas website:

<http://www.juliafchozas.com/projects/coe-calculation-tool/>

The User Guide has been filled as a Technical Reports of Aalborg University (DCE Technical Report No. 161). This User Guide describes comprehensively the development of the COE Calculation tool, the assumptions in the tool, formulas used, background information and case studies that validate the functioning of the tool.

The link below provides direct access to the User Guide (version 1.6):

<https://www.dropbox.com/s/lgpw7hyfo85bp6b/User%20guide%20to%20the%20COE%20Calculation%20Tool%20-%20ver1.6%20-%20April2014.pdf>

The link below provides access to Quick-start user guide, (version 1.6):

<https://www.dropbox.com/s/tmeg96c3ixnqpd/Quick-start%20user%20guide%20to%20the%20COE%20Calculation%20Tool%20-%20ver1.6%20-%20April2014.pdf>

The link below provides direct access to the Excel tool (version 1.6):

<https://www.dropbox.com/s/h5gpxp55k6l9iev/WECs%20COE%20Calculation%20Tool%20-%20ver1.6%20-%20April2014.xls>

#### *How the project results will benefit the environment*

The COE Tool act as an economic assessment tool of wave energy projects. This assessment helps to identify which development areas and WEC components have a high impact on the final COE value. Therefore, the COE Tool helps to identify the areas that need further R&D.

This will help to reduce the COE value for wave energy projects.

The contribution of wave energy into our energy systems brings an environmental benefit for our societies. The more wave energy we harness, the less fossil-fuel sources we need to consume. Wave energy electricity generation is also carbon dioxide emissions-free. Moreover, the carbon foot-print of wave energy technologies have proved to be low.

#### **1.4 Utilization of project results**

The organisations involved in this project expect to use the final product for their own business, provided the Tool can be freely-downloaded from the Internet.

One of the most outstanding activities related to the future of the COE Tool is the common-work that will be carried out within the chapter of the International Energy Agency (IEA) who works with ocean energies: the international organisation OES (Ocean Energy Systems).

The project will be a collaborative work between Denmark, Portugal, the UK, the European Commission, US and Ireland. It will have duration of one year (starting in middle 2014) and it

aims to set-up the background for a new Annex (to be established by the end of 2014 or beginning 2015).

In this project The Danish COE Tool will be compared with other software currently available for the economic assessment of WECs. The Danish COE Tool will also be utilised to derive a case study showing the economic evaluation of WECs and to recommend R&D areas that will help to reduce the COE of WECs.

Additionally, the COE Tool plays an important role for the established work within the Danish Partnership of Wave Energy. The Partnership is carrying-out research on the development areas which lead to high R&D costs. The Danish tool aims to help to identify the areas in need for further R&D; this will eventually help to reduce the cost.

Besides, there is major and world-wide interest to the tool, mainly due its simplicity, transparency and for being open-access. The interest is international, and encompasses research institutes, technology developers, governmental energy agencies, academia, etc.

Project partners have also been very active in disseminating the COE Calculation Tool. Some of the past and coming dissemination activities are described below:

- The COE Calculation tool was presented at one of the wave energy sector's most important conference: EWTEC Conference – the European Wave and Tidal Energy Conference, held in Aalborg. The event was organised by Aalborg University (Sept 2013).
  - o The tool was presented with a Poster, a Conference Paper and with Demo Sessions. Poster and Paper title: "An Open-access Cost of Energy Calculation Tool for Wave Energy Projects: The Danish Approach"
  - o Demo sessions: demo session of the tool were organised upon participants request. 5 demo sessions were held with about 20 participants.
- The COE Calculation tool has been presented to the Danish wave energy sector at two meetings of the Danish Wave Energy Partnership, one held in Hanstholm, in Sept. 2013, and another one held in Energinet.dk on 31<sup>st</sup> January. It might be presented again on 7<sup>th</sup> April 2014.
- On 31<sup>st</sup> January there was also a meeting with Energinet.dk to discuss the changes made to the COE tool, and updates on calculation methods.
- In November and December 2013, the tool was presented to IT University of Copenhagen, who are running the project in wave energy named "Alien Energy". It will be presented again for IT University on March 2014.
- Julia F. Chozas will present on March 2014 the COE Tool in Cork, Ireland, in one of the only Masters dedicated to ocean energies, the "All-island master's in marine renewable energy".

## 1.5 Project conclusion and perspective

### *Conclusions*

The main purpose of the project has been fulfilled: The project has released a final version of the COE tool.

- The COE Calculation tool has been developed and improved: the calculation principles, the economic parameters, the user interface and the user guide.
- The COE Calculation tool has been highly disseminated among its future users and other potential users.

### *Future context of the COE Calculation tool - Perspective*

The potential of wave power around the globe is very large. In Denmark alone, it has been assessed that 15% of the electricity consumption can be provided by wave energy technologies deployed in Danish waters<sup>1</sup>.

There are some challenges ahead before it is possible to harness the potential of wave power in a large scale. Among these challenges, two of them are of special importance. Firstly, wave energy converters need to prove their long-term survivability into the harsh sea environment as well as long-term operation; and secondly, they need to be cost competitive. This project is directly related to the latter factor.

At present time, one of the major challenges for the wave energy sector is to reduce its cost of energy. One of the sector's aims is to get lower cost of energy values that could foster wave energy as a realistic alternative of conventional electricity generation and as a complement to other renewable energy sources.

Calculation of the cost of energy (COE) is done by most device developers. However, these calculations are based on different assumptions and different methods, which are not described or specified, hence making results incomparable and non-transparent.

In this context, the project has developed a common accepted COE calculation tool that makes economic calculations transparent and comparable among various converters. To achieve that, calculations do not only focus on the output economic parameters but on the input values and assumptions.

It is expected that the main project result (The COE Tool) boosts the development of wave energy due to the following reasons:

- It allows targeting the components/aspects with highest impact on the cost of energy.
- It helps to describe the strategic roadmap to reduce the cost of energy.
- It enhances transparency of claimed power productions, and allows equitable comparison of wave energy converters.

<sup>1</sup> Kofoed J.P. (2009). "Ressourceopgørelse for bølgekraft i Danmark". Report No.59 for the Clima Commission.



Moreover, it is mandatory that wave energy projects receiving Danish funding track their COE through the COE Tool developed in this project.

### **1.6 Annual export of electricity (only ForskVE)**

This section is not relevant for this project.

### **1.7 Updating Appendix P and submitting the final report**

**Guide:**

- Along with the final report Appendix P must be updated with the financial numbers for the entire project at [www.forskel.dk](http://www.forskel.dk)
- Please view our guide "Online procedures" on how to update and submit Appendix P and how to submit the final report. The guide can be found on our website [www.energinet.dk](http://www.energinet.dk)

*(Please delete this guide, before submitting the interim report to Energinet.dk)*