Wave energy factors and development perspective analysis in Latvia

Jānis Beriņš
Power and Electrical Engineering faculty
Riga Technical University
Riga, Latvia
e-mail: janis@irbe.apollo.lv

Mg. Juris Beriņš
Automation and Computer Engineering faculty
Riga Technical University
Riga, Latvia
e- mail: juris.berinsa@gmail.com

Abstract – this article is about one of the forms of alternative energy sources – marine and ocean wave energy development possibilities in Latvia. Up until now, wave energy is one of the untapped energy sources in Latvia. This "green energy" potential in Latvia is estimated to be around 7.8TWh, and shows a promising possibility of producing 1.12TWh/year. For this purpose, effective hydroelectric power stations, which can convert wave energy into electricity, are necessary. This calls for the development of new technology to produce the necessary equipment – wave energy receivers and converters. The search for such technology, as well as the testing at various stages of development, is ongoing all over the world. The development of the previously mentioned equipment depends on the number of specialists involved, the professionalism, motivation, and constant budget size. The creation of such equipment in Latvia could become a critical argument for the establishment of such specific equipment factories. In this case, Latvia would take its place in the European renewable energy industry, whilst enjoying the growing industrial leverage and the improving import-export balance advantages. Marine spatial planning with the appropriate zoning of wave hydroelectric power stations is an important cornerstone for this development of this significant macroeconomic branch

Key words – *wave energy; wave height; wave frequency; energy converter; renewable energy; marine wave potential; generating energy, WEC*

I. INTRODUCTION

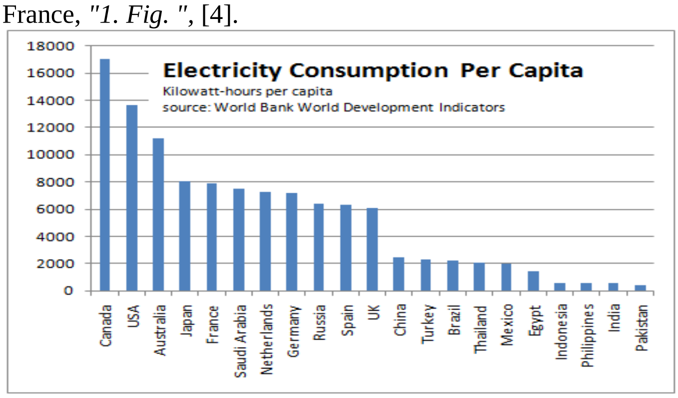
World energy consumption increases with the number of inhabitants, along with the nation's technical economic development. Currently there are approximately 7 billion people on earth, and in accordance with UN forecasts this figure will rise to 9.2 billion by 2050. The demand for both energy, and the need for a cleaner environment, encourages the public to pay more attention to more sustainable energy possibilities, as well as sources of energy which leave a smaller negative impact on the environment, including the currently untouched.

In recent years, European countries have met a series of socio-economic, climate, and geopolitical challenges and changes. These negative trends encourage us to devote more attention to energy independence.

Latvia, along with some other small countries, with its economic policy, low population density, and historical reasons is on the outskirts of the European Union's economic life. Its macroeconomic indicator – national income per capita, the average standard of living, import-export balance and the manufacturing share in the economy, has been low since the regaining of independence. The result is – unemployment and a large chunk of the population emigrating. Being energy dependent on other countries makes the situation more precarious. The need to make the previously mentioned things right urges the nation to do more with our national resources to strengthen society and the states wealth and stability.
The long-term strategy for Latvia for 2030 foresees that, during this period household heat consumption must be reduced, natural gas and electricity imports must be reduced by 50%, as well as increasing the amount of utilised renewable energy in total by 50%, must be achieved. This means that the Latvian energy sector is planning for the increase in energy efficiency and the use of renewable resources [1].

Energy production from marine and ocean waves can become an important component in the energy industry. Wave energy conversion is an emissions-free form of electricity production.

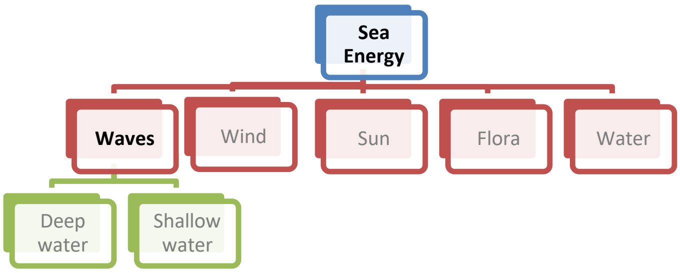
The potential for electricity production that could be produced from the world's oceans and marine waves is estimated to be at least 2,000 TWh / year [2-3]. This amount of electricity would be adequate enough for 250 million people with an average per capita consumption of 8000 kWh / year, which can be observed in such countries as Japan or France, *"1. Fig. "*, [4].



1. Fig.

Electricity consumption kWh/ year per capita [3].

II. THE SEA AS A SOURCE OF ENERGY



2. Fig.
The main form of energy in the Baltic Sea.

Latvia is surrounded by the Baltic Sea which is its maritime territorial waters. The maritime area can be divided into different kinds of energy *"2. Fig. "*. One of them is marine waves. Depending on the length, and the depth of the body of water in a certain area, waves can be divided into: deep water, offshore and shallow water waves. This distinction is necessary because each type of wave energy is determined by different regularities. Deep-water waves exist in a part of the water area where the depth is always greater than or equal to half the wavelength. Shallow water area waves exist at depths of less than half of the wavelength. Shelf waves exist at a depth where the majority of cases the water area depth is greater than or equal to half of the wavelength. There are rational reasons as to why it is worthwhile to examine the possibilities of obtaining energy from offshore waves. Undoubtedly, the most energy is in deep water waves, as they have the smallest energy losses due to refraction. However, the water area depth increases with increasing distance from the coast, where the possibility to connect to the electricity distribution networks becomes more expensive due to the distance, which is an argument for the higher connection cost value. Wave energy is proportional to the wave height H squared, and the wave period T. Wave height maximum values are recorded much less frequently than others. This means that in each individual economic situation there will be a maximum deep water wave height, which will pay off the power to transform the energy, and this wave height, will always be lower than the maximum water areas H statistical measurement values. It is because of this reason that wave power plant design and thorough research must be carried out. One of these tasks is to calculate the optimal depth of the water area on the basis of wave height and period statistics and the financial efficiency of the power plant. Due to rare extreme maximum wave height anomalies and connection costs, the depth will be in the offshore zone.

III. THE INDUSTRIAL APPLICATION OF WAVE POTENTIAL IN LATVIA

In Professor J. Greivulis, A. and L. Avotiņš Kalnins publication, "The Baltic Seas potential for wave energy transformation", [5] an assessment of the Latvian part of the Baltic Sea wave potential was made. Wave energy potential parameters and calculations are linked:

1) The economic importance of the identified;
2) The designing of power station equipment;
3) The available energy in the operational forecast.

In order to identify the potential economic importance of wave energy it is necessary to make a rough estimate. For the sake of the estimate, the basis for the possible industrial significant sea wave power plant (SWPP) zone let's take the Latvian Western coast, where the absorption length is 140 km and the depth is at least 20 m. This figure is chosen because, starting from this point and deeper, most waves are included in the deep water category where water area depth h, and wavelength λ, is equal to h / λ> ½, [6]. With decreasing depth more and more waves become subject to wave refraction, [6], thus losing energy. Therefore, more wave energy can be absorbed from the deep wave zone. Deep-sea wave energy can be calculated using the following expression, [6]:

$$E = \frac{fgH^2\lambda b}{8} \quad (1),$$

where:

E – wave energy, Ws,
f – fluid density, kg/ m^3,
g – freefall acceleration, m/ s^2,
H – wave height, m,
λ – wave length, m,
b – wave width, m.

In practice the measured and archived values are – wave height H, and period T, which are not in formula (1). That is why we shall use different relationships/connections between deep water waves so that it will be possible to express the missing value of wavelength λ. From the equation for wave speed, [6]:

$$c = \frac{\lambda}{T} \quad (2),$$

where:
c - wave velocity, m/s,
λ – wave length, m,
T – wave period, s,
and the other wave velocity formula [6]:

$$c = \frac{gT}{2\pi} \quad (3),$$

where:
c – wave velocity, m/s,
g- freefall acceleration, m/s^2,
π- constant circumference.

Consequently,

$$\frac{\lambda}{T} = \frac{gT}{2\pi} \quad (4),$$

and

$$\lambda = \frac{gT^2}{2\pi} \quad (5),$$

Thus, finding the appropriate connection between wavelength and period in deep water waves. Placing this into the energy formula (1), we obtain the connection:

$$E = \frac{fg^2H^2bT^2}{16\pi} \quad (6),$$

which we shall use to calculate the Latvian annual wave energy potential estimate calculation. Before starting data collection in the water area of interest, we will use existing data summaries from the Baltic Sea area where such data is currently available and, where the appropriate average wave height indicators are presumably lower. Upon receipt of the statistical data of H and T along the Latvian shores, it would be necessary to carry out repeated calculations for the precision of the amount of energy. They are the H and T measurements in the Baltic Sea Arakona basin *„Fig. 3"*, [7], recording the daily averages for the period from 1991 to 2001, [8]. This data is presented in *1. table*. Totalling all the values from the 6th column we obtain the total estimated wave energy calculation for the Baltic Sea waters of the Latvian Western coast, 140 km long front line and it is 7,806 TWh/year. Assuming that the efficiency of the wave receiver is 80%, the energy convert efficiency factor – 20, assuming network losses of 12,5%, we can assert that the potential industrial use of electricity is 1,124 TWh/year. The electricity output will fluctuate during any given year due to the changes in the potential of the wave, and due to wave direction. According to the Latvian Statistical Bureau data in 2014, Latvia produced 5,058 TWh of electricity.

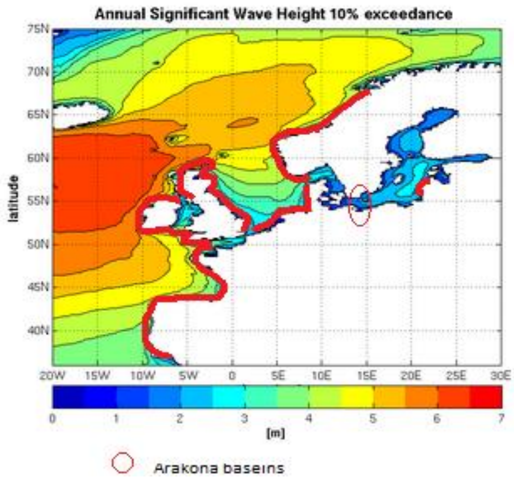
IV. The Use of Technology And Publication review

There are at least 140 different scientific institutions in the world that deal with wave energy conversion solutions, with the aim of finding the most efficient method, and they are involved in around 200 different projects since 2000. A good review is given by Hosna Titah-Benbouzid and Mohamed Benbouzid including machinery classification in their publication „Ocean Wave Energy Extraction: "Up-to-Date Technologies Review and Evaluation", [9]. In an edition of IRENA Ocean Wave Energy Technology Brief 4, 2014 June edition, [10] carried out a more detailed classification of power plants and electricity production cost calculations, and even their forecasts for 2050. This and other publication link summaries are found in source, [11]. A comparison of various different equipments absorbed energy is outlined in „Proceedings of the ASME", [12]. A number of projects are classified by their readiness according to the internationally accepted TRL system. The distribution of WEC projects by country is shown in *„Fig.4"* wave energy developers 'Orkney European Marine Development Centre Ltd' (EMEC) classify 8 main wave energy converter (WEC) types, demonstrating the operational principles in source, [13].

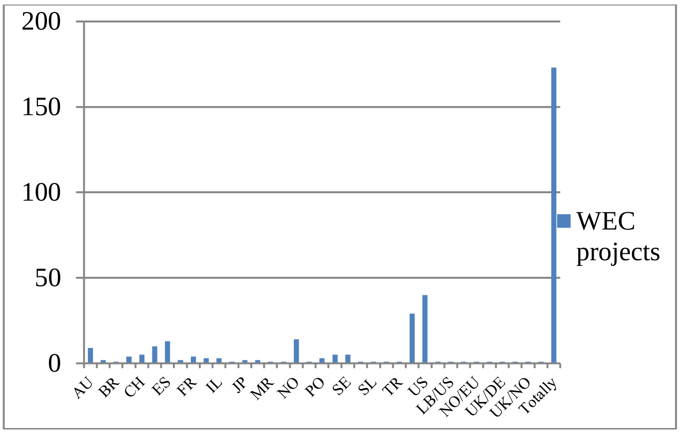
A – attenuator; B – point absorber; C – oscillating wave oscillation converter; D – oscillating water column; E – overflow device; F – submerged pressure differential devices; G – wave pressure equipment; H – spinning/rotating mass installations; I – other equipment. Wave energy conversion projects are listed by WEC type. *„5. Fig."*, [13].

1. table
Latvia's W coast (140 km) yearly wave energy potential estimate calculated results

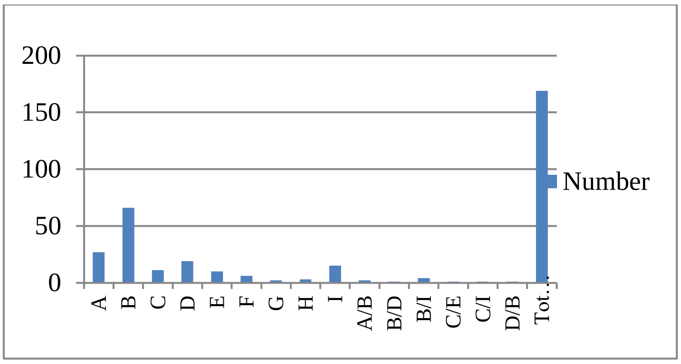
Wave action time, %	Wave height, H (m)	Wave period, T (s)	Energy of one wave, E (kWh)	Annual wave number	Energy of waves, E (TWh/ year)
1.	2.	3.	4.	5.	6.
0,58	0,18	1,00	2,5	182 208	0,000
9,38	0,32	1,50	17,0	1 971 584	0,034
14,38	0,43	2,00	55,7	2 267 088	0,126
12,18	0,56	2,10	102,2	1 828 754	0,187
11,78	0,68	2,30	183,7	1 614 887	0,297
9,38	0,80	2,50	295,5	1 182 950	0,350
8,98	0,91	2,80	490,2	1 011 154	0,496
6,98	1,05	3,00	735,0	733 504	0,539
6,18	1,16	3,20	1 027,9	608 820	0,626
4,98	1,27	3,40	1 399,1	461 704	0,646
4,18	1,43	3,60	1 969,4	365 973	0,721
3,38	1,52	3,80	2 501,6	280 320	0,701
2,58	1,77	4,00	3 756,8	203 232	0,764
1,78	1,89	4,30	4 915,9	130 381	0,641
1,38	2,01	4,50	6 121,0	96 555	0,591
0,98	2,14	4,75	7 694,0	64 916	0,499
0,58	2,25	4,90	9 081,8	37 185	0,338
0,38	2,38	5,00	10 536,2	23 827	0,251
100,00				**13 065 044**	**7,806**



3. Fig.
Wave parameter H and T measurement points in the Baltic sea Arakona basin, and the Latvian SWPP Equipment factory product target audience. [7]



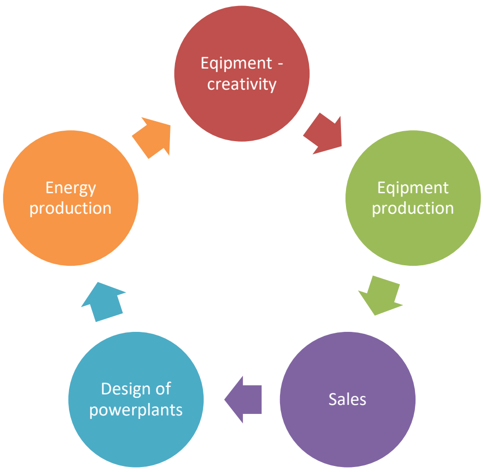
4. Fig.
Number of WEC projects by country



5. Fig.
WEC type distribution in actual projects

V. Economic Sector Strategy Opportunities In Latvia

A defining functional scheme of the wave energy sector is shown in *"Fig. 6."*



6. Fig.
Wave energy sector structural scheme

There are three main scenarios in relation to the Latvian marine wave energy industry:

1. To overlook the marine wave potential and the relevant sector- related engineering;
2. Import equipment for marine power stations and produce electricity;
3. Develop equipment creativity, produce the equipment, design power stations and produce electricity.

In order to establish the most developed and economically prosperous society the obvious path would be the third point because: it includes innovation, which ensures technological progress; equipment manufacturing, which gives rise to an export trade balance to improve the economy's resilience during crisis periods and an opportunity to maintain high employment which in turn promotes a positive demographic process. An increase in electricity production promotes energy independence.

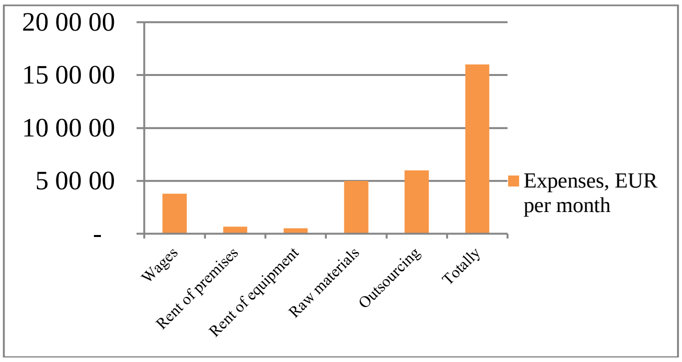
VI. Perspective Developement of The Wave Energy Sector

A. The possibility to create equipment for the construction of a profitable and safe marine wave power station.

Currently in Latvia research and the creative work takes place in the form of individual projects. For the best results, it is necessary for the following points to be able to work independently:

1) *A small group of researchers who examine industry related phenomena, and deal with equipment and nodal development;*
2) *Constructors office which deals with manufacturing technology development solutions, technical calculations and hardware, nodal and installation drafting;*
3) *Laboratory equipment model testing and measurements;*
4) *Experimental factory for the nonstandard production of parts and set up of prototype models*

The suitable budget for the conditions in Latvia and the presented task are shown in *"7. Fig"*.



7. Fig.
Wave conversion equipment development monthly budget EUR

8. Fig.
Latvian wave energy industrial use and Perspective Research Area

A. Legal basis to set-up of wave power- plants.

Maritime Sight Plan (MSP) the main legal documentation needed to ensure the establishment of Latvia's sea wave energy station is at the moment only at the first reading and has to go through six more before it comes into force. According to EP directive 2014/89/ES (2014. 23.July) point 22, [14] the establishment of MSP has to be such as to obey other judicial acts, for instance Directive 2009/28/ EK, [15] which states that at least 20% of renewable energy resources should be in place by 2020. Despite the fact that the MSP process has been started the Latvian government has not yet taken steps to support it. This means that about 9,478 Twh/year MSP of the ability to develop CO2 free natural resources would be left with none or very minimal growth till 2030!

It would also be contrary to the European Parliament and Council Directive 2014/89 / EU (23 July 2014) 4 and 13 of [14], as well as conducive to renewable energy leverage. MSP does not provide for the maximum possible zoning of wave power stations, at the time when they will provide a competitive unit wave energy transformation will occur in contradiction with the standard ISO 50001, [16] requirements, which provides an economic use of energy in all institutions, businesses and organizations. Since the state is an organization, it will be responsible for ignoring the above standard without sufficient wide area MSP SWPP.
MSP should be applied to the construction zone SWPP Latvia where there could be wave energy sector development, *"8. Fig."*.

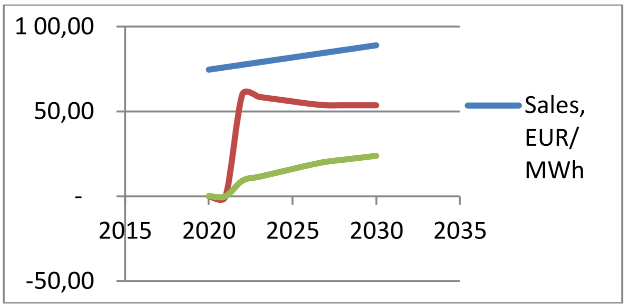
B. Financial sources of wave power plants.

SWPP Latvian establishment can become, and it has become a national energy independence argument. In order to identify potential sources of financial SWPP creation, two conditions are important:

1) The power plant must be viable (lucrative and safe) in the existing market and environmental conditions;

2) Competition and ethical compliance should avoid interest within the State capital.

In these circumstances, and given the significant level of investment needed it is most appropriate to establish an open joint stock company by inviting domestic and foreign investors and to explore the possibilities for loan fundraising. Wholesale electricity prices, [17], the power plant costs and profit forecasts curves EUR / MWh shown in *9. Fig*.



9. Fig.
Wholesale electricity prices, production costs and profit forecast.

C. Wave power station equipment Factory Establishment.

SWPP equipment factory establishment can become a positive factor for the socio-economic life of Latvia bringing it closer to the most developed countries of and contributing to the improvement of a number of macroeconomic indicators:

1) *Import - export balance;*
2) *Employment and living standards;*
3) *State Budget revenue increase;*
4) *National income increases.*

Latvian SWPP equipment factory product target audience consists of countries with coasts in the area of prospective SWPP - Baltic States, Norway, Denmark, Germany, Great Britain, Ireland, the Netherlands, France, Spain and Portugal "*3. Fig.* "[7]. some industry key national origin wave power generation potential is summarized in *2. table*, [18].

However, there must be a number of prerequisites for such a power station to be built in Latvia:

1. The development of the prospective wave energy conversion power station in Latvia will have more opportunity to create a SWPP equipment/device factory. On the other

2. table
Some important countries wave power potential [18]

State	TWh / year
England	43- 64
Ireland	21- 32
Portugal	*12- 18
Spane	*10- 16
France	*12- 18

hand, the development of such equipment is more likely to happen during the power stations original design time DT → 3 years;

2. Undoubtfully an argument is the building of SWPP in the Baltic Sea area which is independent from MSP where such a development accords to ISO 50001 [16];

3. The existence of a suitable site with appropriate infrastructure and available specialists. Such a successful place in Latvia could be Liepaja, with its harbour. Liepaja Ports advantages are its area, with the ability to store power station modules and pontoons, and ready modules, before they are sent to be set up. The second advantage being the possibility of navigating all year round, this would be crucial for the delivery time execution;

4. A favourable business environment that consists of a smaller tax burden with consistency and predictability, the states and municipal authorities acceptance, bureaucratic service comfort and speed. To this should be added a fast track production of a qualitative MSP with an economically viable zone for SWPP development;

5. The geopolitical climate. Presently, the geopolitical climate in Europe is not conductive to attracting investors because of the increased risk of war. One must be aware of the fact that one of the most important, if not the most important, cause of the existing geopolitical situation is a lack of effort to strengthen domestic energy independence. That is why there is now a political will to turn the situation around for the better. There are no other options to correct past mistakes and to activate work on starting a new energy company, including the SWPP, current energy company modernization and economic energy usage in accordance with ISO 50001, [16] the widest possible energy production and consumption sectors.

Equipment Plant Sustainability is objectively necessary as a better functioning of technical innovation, expanded and available to customer's sales office activity as well as power plant design. It is planned that the factory will place orders for all standard components, assemblies and some non-standard parts and subassemblies to domestic and foreign suppliers, bearing specific non-standard parts and assemblies manufacturing and module assembly plants in our own hands. The factory's establishment site selection is necessary to assess the availability of infrastructure and suppliers of raw materials and logistics.

VII. CONCLUSIONS

1. The imbalance of energy production and consumption creates geopolitical instability.
2. Despite the demographic challenges, the wave energy sector may become a significant incentive for the Latvian economy due to the dynamic energy demand in the world.
3. Wave power plants could increase the energy production magnitude/volume by 14% in Latvia.
4. In order for the development of the wave energy industry in the world, more effective basic power station equipment is needed.
5. Marine wave energy can become an important factor in improving Latvia's economic environment.
6. The development of innovative wave power station equipment is the key to wave energy industries sustainability.
7. In a successful innovation, the first to make the Baltic Sea SWPP able to start work in 2022. To do this, sufficiently effective to develop wave energy receiver and converter must be conceived and built by SWPP.
8. For the precision and prediction of wave energy potential, continuous and long-term measurements of H and T parameters must be made.

For the successful production of basic SWPP equipment there are necessary preconditions for manufacturing equipment. There are a number of conditions - including:

a) SWPP zoning existence MSP,

b) a favorable business environment.

BIBLIOGRAFY

[1] Latvijas republikas Saeima., Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam.

[2] J. Crus Ed., Ocean Wave Energy: Current Status and Future *Perspectives*. Springer, Berlin, 2008.

[3] J.G. Vining and A. Muetze, ―Economic factors and incentives for ocean wave energy conversion,‖ *IEEE Trans. Industry Applications*, vol. 45,n°2, pp. 547-554, March-April 2009.

[4] Cruz J.; Gunnar M.; Barstow S.; Mollison D. (2008). Joao Cruz, ed. *Green Energy and Technology, Ocean Wave Energy*. Springer Science+Business Media. p. 93. ISBN 978-3-540-74894-6.

[5] Avotiņš A., Greivulis J., Kalniņš L. Baltijas jūras potenciāls viļņa enerģijas pārveidošanai. *Enerģētika un elektrotehnika*. Nr.23, 2008, 213.-224.lpp. ISSN 1407-7345.

[6] Michael E McCormick "Ocean Wave Energy Conversion" Dover Publications Inc., New - York 2007.

[7] http://ocean.dmi.dk/wavestat/index.uk.php

[8] T. Soomere, R. Weisse, A. Behrens „Wave climate in the Arkona Basin, the Baltic Sea", Published in Ocean Sci. Discuss.: 21 November 2011, 293. lpp. un 295. Lpp

[9] Hosna Titah-Benbouzid, Mohamed Benbouzid. Ocean wave energy extraction: Up-to-date technologies review and evaluation. IEEE. IEEE PEAC 2014, Nov 2014, Shanghai, China. IEEE

[10] IRENA Ocean Wave Energy Technology Breaf 4, 2014.

[11] http://www.aplacetoinvest.com

[12] Proceedings of the ASME 2011 30th International Conference on Ocean, Offshore and Arctic Engineering OMAE2011 June 19-24, 2011, Rotterdam, The Netherlands.

[13] http://www.emec.org.uk/marine-energy/wave-devices/

[14] Eiropas Parlamenta un Padomes Direktīvas 2014/89/ES (2014. gada 23. jūlijs) 22. punkts

[15] Direktīva 2009/28/ EK

[16] ISO 50001

[17] http://www.theccc.org.uk/wp-content/uploads/2014/12/TechAnnex.pdf

[18] https://www.thermalfluidscentral.org/, „Wave Energy".