Technical Economical Assessment of JVS in the Baltic Sea Latvian EEZ

Considering the data of the Latvian *EEZ* wave potential calculation in the Baltic Sea as discussed in Chapter 1 of this work, we will look at it from a 200 km long (consisting of several stages with different input parameters) *JVS* perspective. Let's take the standard calculation method Nett Present Value *(NPV)* as the basis for calculations and use the expression (1) to calculate the input potential of the electricity generated in the calculations of the generated electricity, as they were historically in 2011 using the naive forecasting method.

The total *JVS* utilization factor includes the multiplication of all efficiency coefficients from the transformation of the wave power to the energy connection *ST*.

In this calculation, we will consider / analyze only the process in which wave energy is transformed into electricity.

The coefficient η_T is used to determine this transformation characterized by equitation:

$$\eta_T = \eta_V \times \eta_H \times \eta_P \times \eta_F \times \eta_L \times \eta_M \times \eta_E \,, \tag{1}$$

where

η_V – Kinetic energy distribution coefficient in volume,

η_H – Horizontal flow separation ratio (0.5),

η_P – Flow utilization factor for estimating the flow of the flow through the turbine (Beitz / Glauerts 0.5926),

η_F – Form factor (π / 4),

η_L – Turbine hydraulic efficiency,

η_M – Mechanical efficiency (bearing, seal 0.95),

η_E – Efficiency ratio of the electric generator.

Let Morozov's equation (2) describes the relationship of the known *APRLHK* turbine T1 model and geometric similar turbines T2 with diameter D2 as in 3.2.4. (2):

$$\eta_{L2} = (1 - (1 - \eta_{L1}) \times \sqrt[5]{\frac{D_1}{D_2}}) \,, \tag{2}$$

where

η_{L2} – Efficiency coefficient of a geometrically similar turbine,

η_{L1} – Efficiency ratio of known turbine,

D1 – Diameter of known turbine (0.9 m),

D2 – Diameter of the geometrically similar turbine.

Assuming η_{T1} and η_{T2} expressions based on equation (1), dividing both of these equations with each other and by deducing the same variables we will express them as equation (3):

$$\frac{\eta_{T1}}{\eta_{T2}} = \frac{\eta_{L1}}{\eta_{L2}} \,, \tag{3}$$

From (4.3) known turbines η_{L1}:

$$\eta_{L1} = \frac{\eta_{T1}}{\eta_V \times \eta_H \times \eta_P \times \eta_F \times \eta_M \times \eta_E} \,, \tag{4}$$

where all the values on the right of the equation are known. Thus, knowing η_{L2}, η_{L1} and η_{T1} from the expression (1), the coefficient of utilization of the geometrically similar turbine η_{T2} is calculated.

On the basis of the data of the Baltic Sea Latvian *EEZ* wave potential data described in chapter 1 of the work at the control points P1, P2, P3, P4, P5 and P7 at the turbine with D = 9 m and η_{T2} = 0.25, we will make economic calculations.

In order to find out the greatest energy probability we will multiply the corresponding wave power with the time that these waves exist and rank in increasing order of energy value. Approximately 70% of wave power is in the range up to 39 kW / m (Table 1).

Technically, the *JVS* turbine power range is limited and the rest of the wave energy is within a wave power range that is far from 39 kW / m. In this interval, the *JVS* will continue to work in a submerged position. Let's choose the maximum power of the *JVS* turbine at *jvl-A, (*where *A* – amplitude) at a power of 39 kW / m. In this range, the dependence of the specific amount of wave energy E_v (kWh / m) on the specific wave power P_V (kW / m) is shown in Figure 2.

Table 1.

Dependence of incoming wave energy E_v from wavelength average power P_v at control point P1

Ev **(kWh / m)**	**Average power** ***Pv*** **(kW / m)**	**% of the total energy** E_v
522	37	
585	**39**	
883	35	
914	33	
966	23	
1 052	29	
1 070	27	
1 396	11	
1 442	17	
1 545	25	
1 595	21	
1 643	15	
1 869	19	
3 052	1	
3 079	3	
31 508		**70.05**

Technically, the *JVS* turbine power range is limited and the rest of the wave energy is within a wave power range that is far from 39 kW / m. In this interval, the *JVS* will continue to work in a submerged position. Let's choose the maximum power of the *JVS* turbine at *jvl* at a power of 39 kW / m. In this range, the dependence of the specific amount of wave energy E_v (kWh / m) on the specific wave power P_V (kW / m) is shown in Figure 1.

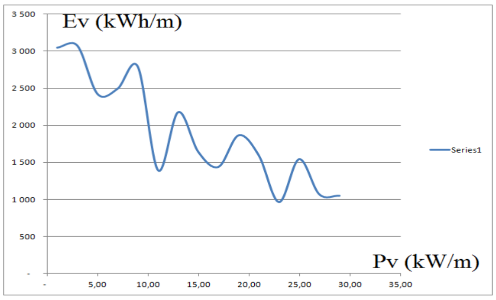

Fig. 1. Dependence of specific wave energy E_v (kWh / m) on specific average wave power P_v (kW / m)

The full spectrum of the control wave P1 annual specific energy E_v (kWh / m) is shown in Figure 2.

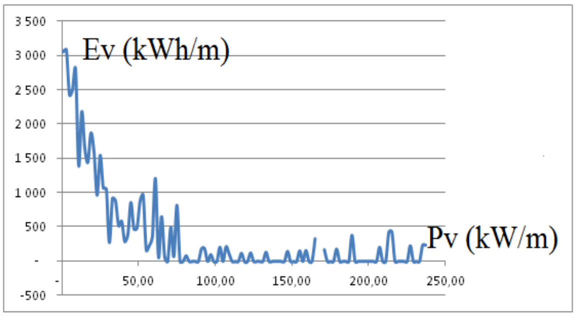

Fig.2. Control P1 full wave specific energy E_v (kWh / m) distribution depending on wave specific power P_v (kW / m)

Based on the data of the Baltic Sea Latvian *EEZ* wave potential data described in chapter 1 of the work at control points P1, P2, P3, P4, P5 and P7 at the turbine with D = 9 m and η_{T2} = 0.25, we will make economic calculations for possible *JVS*, which is characterized by distances depending on from input data and existing navigation situations:

1. With P1 characteristics the *JVS* is 19.4 km long;
2. With P7 characteristics the *JVS* is 24.85 km long;
3. With P2 characteristics the *JVS* is 55.60 km long;
4. With P3 characteristics the *JVS* is 61.73 km long;
5. With P4 characteristics the *JVS* is 25.18 km long;
6. With P5 characteristics the *JVS* is 13.65 km long.

Specific investment forecasts are shown in table 2. Estimates of electricity prices were used in the calculations as in table 3.

Table 2.

Specific investment forecasts

Item	Investments, EUR
Price of turbine	7 000.00
Installation costs	10 000.00
Infrastructures costs	9 000.00
Infrastructure installation	12 000.00
Total 1 turbine	38 000.00

Table 3.

Episode of electricity wholesale price forecasts in EUR / kWh

Year									
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0.0152	0.0060	0.0173	0.0268	0.0412	0.0225	0.0059	0.0338	0.0072	0.0170
0.0249	0.0212	0.0164	0.0167	0.0066	0.0203	0.0206	0.0101	0.0101	0.0336
0.0070	0.0086	0.0029	0.0137	0.0239	0.0232	0.0224	0.0209	0.0009	0.0092
0.0171	0.0109	0.0086	0.0027	0.0115	0.0172	0.0301	0.0214	0.0095	0.0213
0.0131	0.0026	0.0140	0.0151	0.0147	0.0364	0.0208	0.0016	0.0227	0.0247
0.0026	0.0138	0.0191	0.0220	0.0194	0.0206	0.0144	0.0024	0.0097	0.0349
0.0144	0.0312	0.0169	0.0377	0.0208	0.0214	0.0478	0.0267	0.0343	0.0478

The interest rate, discount rate and duration of the planning period are shown in Table 4.

Table 4.

Interest rate, discount rate and duration of the planning period

Item	Value
Interest rate	2,60%
Discount rate	2,00%
Period	25 years

Results

Calculation results are shown in Table 5.

References in the table are:

$P_{V\ max}$. – The maximum available power of the incoming waves in kW / m,

$P_{T\ max.}$ – Maximum power of the turbine in kW,

E_{EL}. – Annual electricity production in TWh,

In the technical project, the maximum electrical power of the turbines will be standardized and will therefore differ from the theoretically calculated. The *NPV* forecast for *JVS* P1 is shown in Figure Fig. 4.

Table 5.

Results of the technically-economical calculation of *JVS* modelled in the Baltic Sea Latvian *EEZ*

	P1	P2	P3	P4	P5	P7	Total
$P_{v\ max.}$, kW / m	39	33	34	37	30	34	
$P_{T\ max.}$, kW	88	75	76	84	67	77	
***JVS* length, km**	19.40	55.60	61.73	25.18	13.65	24.85	**200.41**
E_{EL} , TWh	0.19	0.52	0.55	0.26	0.11	0.23	**1,86**
Number of turbines	2155	6178	6859	2798	1517	2761	**22268**
Investments, EUR	81.89	234.76	260.64	106.32	57.65	104.92	**846.18**
***LCOE* with loan, EUR / kWh**	0.100	0.099	0.102	0096	0.105	0.100	**0.100**
***LCOE* without loan, EUR / kWh**	0.092	0.091	0.093	0.089	0.096	0.092	**0.092**

References in the table are:

$P_{V\ max}$. – The maximum available power of the incoming waves in kW / m,

$P_{T\ max.}$ – Maximum power of the turbine in kW,

E_{EL}. – Annual electricity production in TWh,

In the technical project, the maximum electrical power of the turbines will be standardized and will therefore differ from the theoretically calculated. The *NPV* forecast for *JVS* P1 is shown in Figure Fig. 3.

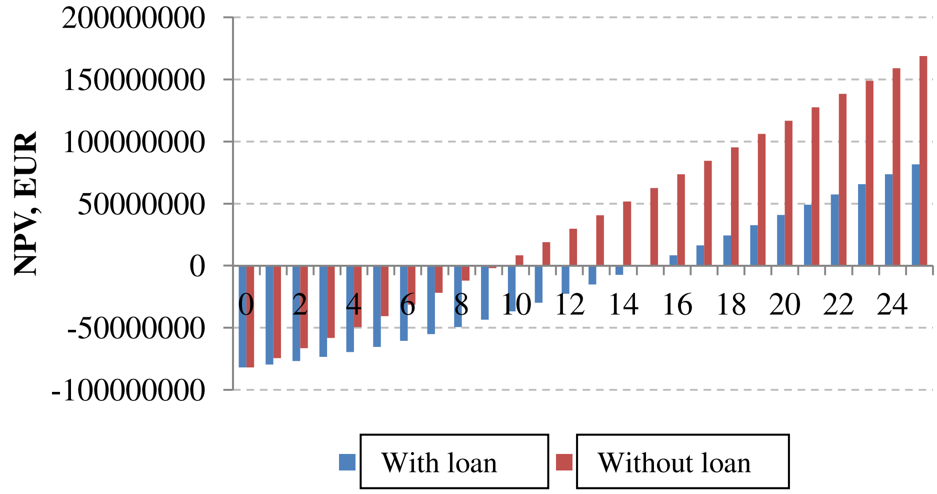

Fig. 3. *NPV* forecast for *JVS* P1 stage

Similar *NPV* projections were also calculated for the remaining *JVS* stages.