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Alternative Energy Usage Types in Buildings and a Proposal for a Generator Working with Wave Energy

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Abstract

The decrease in non-renewable resources, and global warming problem in the world is increasing the interest and demand for alternative energy sources. In addition to the investments made in renewable energies such as solar and wind in various countries, regions with coasts to oceans or seas also make new investments in wave energy.

In this study, by comparing wave energy with other alternative renewable energy types from various angles, an alternative method is proposed for geographical regions without continuous wave generation, unlike previous studies. The basis of the method is to store the water mass pushed by the wave in a high level when the sea is wavy, and to generate energy by using the potential energy of this water body when it is passed to stagnant weather conditions. It is thought that the method can affect the preference criteria of alternative energy use in buildings.

Keywords: *Wave energy, storing energy, energy turbines, clean energy, renewable energy*

Yapılarda Kullanılan Alternatif Enerji Kaynakları ve Dalga Enerjisi ile Çalışan Bir Jeneratör Önerisi

Öz

Dünya üzerinde yenilenemeyen kaynakların azalması ve küresel ısınma sorunu alternatif enerji kaynaklarına olan ilgi ve talebi arttırmaktadır. Çeşitli ülkelerde güneş ve rüzgâr gibi yenilenebilir enerjilere yapılan yatırımların yanı sıra okyanus veya denizlere kıyısı olan ülkeler de dalga enerjisine yeni yatırımlar yapmaktadırlar. Bu çalışmada, diğer alternatif yenilenebilir enerji kullanımları ile dalga enerjisinin karşılaştırılması ana hatlarıyla yapıldıktan sonra, daha önce yapılmış olan çalışmalardan farklı olarak, sürekli dalga üretimi olmayan coğrafi bölgeler için alternatif bir yöntem önerilmiştir. Yöntemin esası denizin dalgalı olduğu zamanlarda dalgayla itilen su kütlesinin yüksek bir konumda depolanması, durgun hava koşullarına geçildiğinde bu su kütlesinin potansiyel enerjisinden yararlanarak enerji üretilmesine dayanmaktadır. Yöntemin dalga enerjisi kullanımını bir derece avantajlı hale getirerek yapılarda alternatif enerji kullanımı tercih kriterlerini etkileyebileceği düşünülmektedir.

Anahtar kelimeler: *Dalga enerjisi, enerjinin depolanması, enerji türbinleri, temiz enerji, yenilenebilir enerji*

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1. Introduction

Energy use in the world is increasing every year and almost most energy sources currently consumed are carbon-based fuels (fossil fuel). The biggest leaps were experienced in the last two years, with an average growth rate of 3.6% in energy consumption per capita and a growth rate of 5.9% in overall energy consumption. The amount of CO_2 released into the atmosphere with the use of fossil fuels was 5 million tons/year in the middle of the 20th century, and today it has approached 40 million tons/year. Fossil fuel resources known around the world are rapidly being used up. The new finds are not as big as those found in the past. If the consumption of fossil energy resources continues at this rate, it is predicted that oil and natural gas reserves will be exhausted at the end of the 21st century, and coal resources will disappear at the end of the 22nd century (Shehadi, 2020).

Turkey's economy is among the fastest growing economies of the G20 countries. In Turkey, energy consumption is increasing in parallel with the world. Approximately 90% of its energy needs are met from fossil fuels. While natural gas and crude oil are imported from abroad, some of the coal is also imported. (KPMG Sektörel Bakış Enerji Raporu, 2020).

The largest share in global energy consumption belongs to buildings with a ratio 40%. Buildings also have a great impact on the environment in their life cycle. Significant energy savings will be achieved when the fossil energy consumption of buildings is reduced by increasing the use of renewable energy sources. Since the end of the 20th century, legal regulations have been made for energy saving, energy efficiency and energy management. Investment incentives and government supports have been provided for buildings in European countries and the USA, and "green building" certificates have been given. As a result, the concepts of "energy efficient building", "zero energy building" and "passive building" have become more common. The common feature of these concepts is to minimize energy use and waste while meeting function-related comfort requirements and services, and to tend towards sustainable and renewable energies (Shehadi, 2020).

In buildings, heat or electrical energy can be obtained from renewable energy sources such as solar, wind, geothermal, biomass and can be used for heating, cooling, lighting and other services. In this study, after a brief review of the positive and negative aspects of renewable energies used as an alternative to fossil energy in buildings, an alternative method that works with wave energy and that can be used in geographic areas without continuous wave generation, unlike existing systems, is proposed.

Wave energy is one of the renewable energy sources that emerge in seas and oceans with the effect of Archimedes principle and gravity. Wave energy is not only an important source of energy, it is also more efficient than many other types of renewable energy. Seasonally, the rate of conversion of sun and wind to energy is between 20-30%. Wave energy is available in approximately 50% of the year. It is clearly seen that it is one of the important resources that should be used in our country, which is surrounded by seas on three sides. (Tezcan, 2003)

The power of a wave is proportional to the square of its amplitude and the period of motion. 40 - 50 kW of energy is generated per meter of a wave’s width of long period and large amplitude (~2m). Like other renewable sources, wave energy does not have a regular distribution throughout the world. There are several high-wave regions across the globe. In both hemispheres, wave movement between ~ 30^o and ~ 60^o latitudes is high with the dominance of the western winds.

Figure 1 shows the distribution of global wave power. In European countries by the Mediterranean coast this ranges between 4 and 11 kW / m annually, and the highest values are observed in the south-western part of the Aegean Sea. While the total wave energy source for Europe is 320 gw the deep-water source along the Mediterranean coast of the continent stands at around 30 gw per year (Tezcan, 2003).

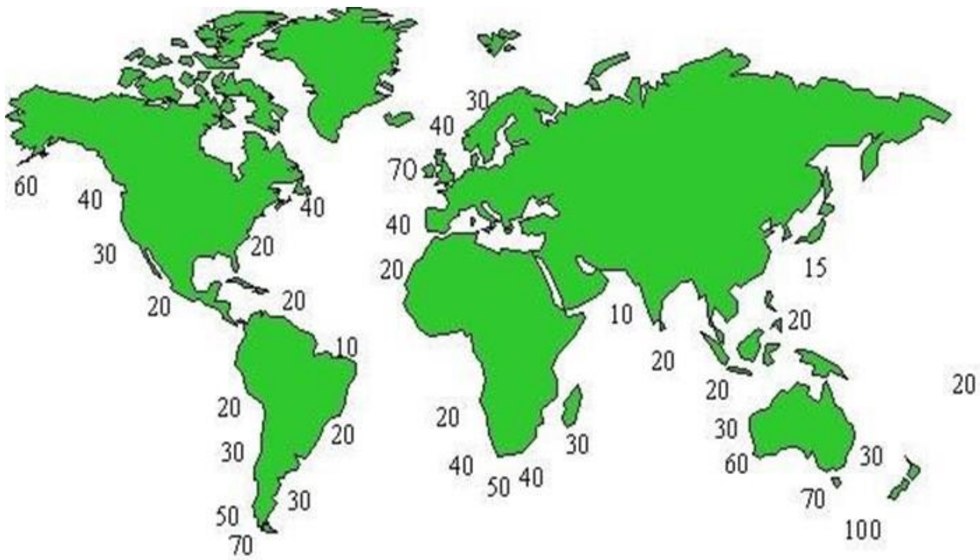

Figure 1. Distribution of wave power across the world (kW/m peak height) (Tezcan, 2003)

The systems that exist are those which produce energy with continuous wave motion the following patents US8970055B2, US7834471B2, US5426332A have been investigated regarding the previous studies on this subject. In the patent number US8970055B2, a model that harvests energy by moving on the sea has been developed. In the patent number US7834471B2, energy is obtained with a spring system depending on the wave motion. In the patent number US5426332A, an electric generator apparatus that produces electrical energy from the tidal movements of a water body by using more than one energy generating system is designed.

This study differs from existing systems. By using theoretical calculations, the study seeks to prove on the pilot system that efficient energy can be obtained in still weather conditions by storing the wave in a high position during heavy sea conditions. In this study, wave energy is stored in a generator installed on the shore by considering hydrodynamic properties. When necessary, electrical energy can be produced and used in any building. Since the system will use the existing energy transmission lines, there is no need for any additional equipment.

2. Renewable Alternative Energy Sources Used in Buildings

The main alternative energy sources used in buildings are mentioned below. The common goal is to save buildings from fossil fuel domination. Depending on the type of energy, a certain amount of installation cost will be incurred at the beginning, but it pays for itself after a certain period of time with the energy bill savings.

2.1. Solar energy

Solar radiation is converted into heat or electrical energy through thermal systems or photovoltaic panels. The efficiency of the panels depends on the amount of the incident radiation and the angle of incidence. Therefore, the same efficiency cannot be obtained for every latitude and longitude degree of the world and for every hour of the day. Energy production depends on the annual sunshine duration of the geographical region where the system is installed. However, solar energy sources are at the top of the list used in buildings because they are sustainable, reliable and clean. The collectors can be designed as integrated with the building or can be installed outside the building. When placed on the building, their effect on the building function and aesthetics should also be taken into consideration. Disadvantages of using solar energy include the shadowing effect of clouds, terrain, or environmental elements, reduced exposures or complete deactivation of collectors, and the tendency of collectors to deteriorate over time.

2.2. Wind Power

Wind energy, like solar energy, is renewable, safe and clean energy without carbon emissions. In the past, wind energy has been used by windmills. Wind turbines today convert mechanical energy into electrical energy. The blades that can be vertical or horizontal axis rotate under the effect of wind, the generator connected to the turbine generates electricity by magnetizing as in hydroelectric or thermal power plants. Vertical axis turbines can catch the wind from any direction. Horizontal axis turbines should be directed to the wind. However, their use is more common. The efficiency of the turbines depends on the continuity and speed of the wind. Medium and small size turbines can be designed as integrated to the building however, as with solar panels, facade function and aesthetics should also be taken into account. Since the wind speed increases as the ground level rises, it is more advantageous to place the wind turbines on high buildings. Aerodynamic noise and electromagnetic field effect that occur in turbine systems integrated to the buildings or installed close to living areas can be counted among the potential disadvantages of wind turbines. Precautions should be taken for these (Şenel & Koç, 2016).

2.3. Geothermal Energy

Geothermal energy is the heat energy of hot water or steam stored in the earth's crust. It is the main energy source of volcanic regions and one of the most efficient renewable energies. Hot water from underground has been known and used in hot spring facilities since the past. Today, geothermal energy is used in the health tourism It also has a wide range of uses from agriculture to industry or electricity generation. The most common use of geothermal energy in buildings is central heating and can also be used in cooling. Most of the equipment such as heat pumps, heat exchangers and connecting pipes are underground, so they are not affected by weather conditions. They do not create a bad image and take up space on the facade of the building. Since there are no heating boilers and chimneys in geothermal energy central heating, there is no emission of carbon and it is advantageous in terms of safety. There are some disadvantages to using geothermal energy. Geothermal fluid can cause water and soil pollution through the circulation of the lower layers of the earth, heat pumps use electrical energy when operating and they run noisy. (Erkul, 2012).

2.4. Biomass Energy

Biomass is an organic material that comes from plants and animals and contains stored chemical energy. Major biomass sources include crop and agricultural waste, wood and forestry waste, cattle, ovine and poultry droppings, slaughterhouse waste and organic waste. Biomass energy is in the renewable energies class, but it is not completely clean energy. Its disadvantages include high water use and low efficiency compared to fossil energies.

2.5. Wave Energy

Wave energy occurs under the influence of wind and gravity. Wave energy does not cause environmental pollution and reduces dependence on fossil fuels. Since the wave density can be predicted in advance, the average amount of energy that can be obtained can be calculated. Wave energy devices are modular and additional devices can be added to the system when needed. It does not constitute any obstacle for the migration of fish and other aquatic creatures. It does not harm the aquatic population. The most important advantage of shore wave generators over offshore generators is that the cabling and energy transfer costs are low since the generator is on land.

Besides all these advantages, wave energy has some disadvantages. Wave energy generators on floating buoys or platforms on shoreline and offshore can create eyesore. In general, wave energy generators need to be placed in appropriate areas as they generate energy depending on the continuity of the waves and energy production will decrease in periods when the waves decrease. Offshore wave energy devices can pose a threat to vessels that cannot see or detect them by radar, so they must be equipped with warning systems. Another disadvantage is the high cost of transporting the energy generated by wave generators installed in the open sea to the shore with long underwater cables (Alternative Energy Tutorials, 2020).

In this study, a system has been developed to minimize all these problems. Its usability has been demonstrated by making experiments and calculations on this system.

3. Method

In this study, the following steps were applied:

- In the first stage, preliminary literature on wave energy were researched.
- In the second stage, a shoreline pilot system was designed (see Figure 3) for the storage of wave energy. Shoreline devices are wave energy devices which are fixed to or embedded in the shoreline that is they are both in and out of the water.
- In the third stage, the 3D printing and metal fabrication of the designed pilot system were industrially created. The crankshafts, the gears, the pistons are 3D printed. The upper and the lower tank are made of stainless steel.
- In the fourth stage, 3D and metal parts were mounted on a wooden base and hose, tap and flange connections were made. The assembly process was completed.
- In the fifth stage, experimental calculations were made and are shown in section 4.
- In the final stage, real environment energy production and feasibility calculations were made through theoretical calculations (Section 4).

3.1. Pilot System Design

A plastic pontoon was positioned within a guide frame and then mounted on a pier by a sea shoreline that has abundant wave movement. In heavy sea, this pontoon moves up and down depending on the height of the wave. By converting this movement of the pontoon into mechanical energy, it was possible to compress the sea water into a small pond or reservoir that was built and mounted at a higher level. For this purpose, a device was designed as a pilot system (Figure 2) based on the principle of Figure 3. In Table 1, the materials used in the pilot system and their tasks are indicated.

Table 1. Materials used for the design of the pilot system

No	Material Name	Duty	Width/Length/ Height	Capacity
1	Wave Motion Motor	Activate the gear mechanism that simulates wave motion.	–	12 V - 150 mA 30 d/d
2	Gear Mechanism	Transmit the movement of the wave to the pontoon attached to it.	–	54 mm down-up movement
3	Pontoon	Simulate the movement of the pontoon by wave energy.	Width: 10 cm, Length: 17 cm Height: 12 cm	–
4	Pool (Stainless steel 0.5 mm)	Represent the equivalent of the sea in theory.	Width: 20 cm, Length: 30 cm Height: 21 cm (approx.)	12,6 liters
5	Gear box	Increase the compressive force of the pump by transmitting the up and down movement of the gear to the pump piston.	–	–
6	Pontoon gear	Transfer the movement of the pontoon to the gear box.	–	–
7	Pump gear	Transfer the movement of the pontoon to the pump.	–	–
8	Piston pump	Compress the water in the pool into the upper tank, moved by the piston connected to the gear.	Inner diameter: 30 mm Piston: 38 mm	29 cm^3/period
9	Upper Tank (stainless steel 0.5 mm)	The equivalent of the upper tank in theory.	Diameter: 20 cm Load: 20 cm	6,28 liters
10	Electric pump	Utilize the potential energy provided by the height of the upper tank and to operate the turbine in theory.	12 V, 2.05 A Compression Height: 5 m	Flow: 15 liters/min
11	Turbine	Generate electricity through the energy of the water compressed from the upper tank.	–	V= 4,78 volt A= 0,30 ampere

12	Drain hoses of pool and upper tank	_	_	_

3.2. Working Principle of the Pilot System

As shown in Figure 2, an incoming wave raises the pontoon as the sea level rises. A vertically attached piston rod connected to the pontoon pushes the S_2 piston up. When the pressure in the cylinder increases, the check valve in the suction pipe closes and the flap on the compression side opens. Then, the S_2 piston compresses the water in the cylinder into the upper tank or into the pond. When the sea descends and as the pontoon goes down, it also pulls down the S_2 piston connected to the pontoon. Due to the pressure drop in the piston, the check valve opens, and the flap is closed by the pressure of the water inside the pipe. While the piston continues its downward movement due to the occurring pressure drop, and since the flap is also open, it absorbs water from the sea through the suction pipe and fills it into the cylinder. The movement period of the pontoon can be assumed to be 4 seconds. (2 seconds up, 2 seconds down).

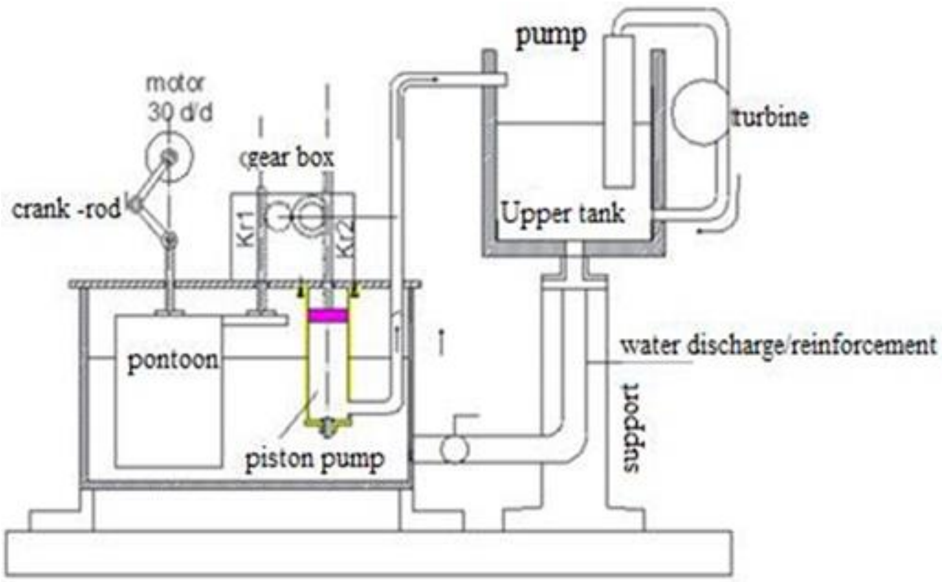

Figure 2. The design of the pilot system used in the experiments

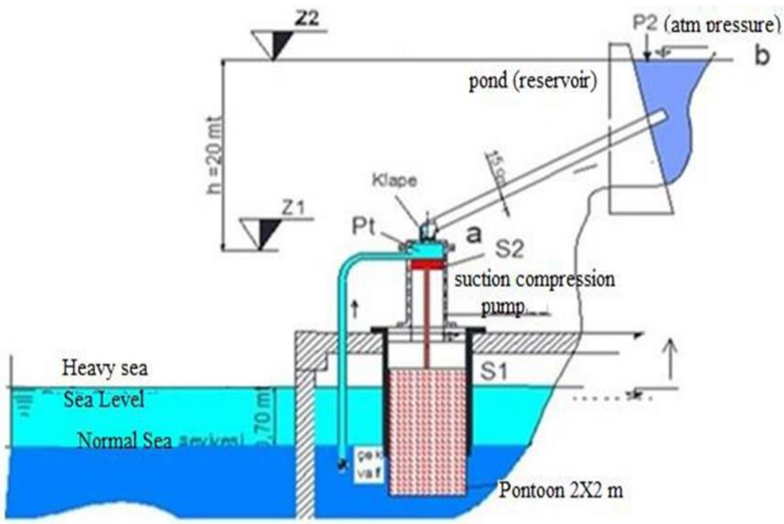

Figure 3. Wave energy generation model

If the tank is built on a riverbed, the system can add an additional capacity to the tank during arid weather.

In the proposed model, a mechanism that runs with an engine of 30 rpm creates the upward and downward movements of the pontoon, which is caused by the sea's surging waves.

Figure 4. Pilot system

4. Findings

In this section, pilot system experimental findings, real environmental theoretical calculations, energy calculation and annual energy generation are given. The experimental equipment is shown in Figure 4.

4.1. Experimental Findings

Pilot system test results and calculations are given below:

Wave Height: 54 mm

Displacement of the pump piston: 3.02 cm

Water compressed by the pump into the upper tank;

In 60 seconds, the increase in the surface of the upper tank water = 2.8 cm. Since the tank has a diameter of 20 cm, the water pumped in 60 seconds amounted to:

$V = (20/2)^2 \times 3.14 \times 2.8 = 879\ cm^3$ (01)

Flow: $Q = 879\ cm^3 / 60\ sec = 14.65\ cm^3 /sec$ (02)

Turbine Efficiency: Measured Voltage: $V_{average} = 4.78$ V, Measured Current: $A_{average} = 300$ Ma

4.2. Real Environment Theoretical Calculations

Pontoon base area = $S_1 = 200\ cm \times 200\ cm = 40{,}000\ cm^2$ (03)

Suction–Compression Pump = Cylinder diameter = 40 cm

Compression surface = $S_2 = 20^2 \times 3.14 = 1{,}256\ cm^2$ (04)

If we take the average wave height as 70 cm, the water lifting pressure that affects the pontoon upwards:

$P = 70\ cm \times 1\ gr/cm^3 = 70\ gr/cm2 = 0.07\ kg/cm^2$ (05)

Total buoyancy of the pontoon:

$F = p \times S_1 = 0.07 \times 40{,}000 = 2{,}800\ kg$ (06)

In the S_2 piston, the pressure transferred to the water: $P_s = P / S_2 = 2{,}800/ 1{,}256 = 2.229\ kg/cm^2$ (07)

$2.229\ kg/cm^2 \times 10 = 22.29$ m (meters water column)

That is, with this pressure the water can rise in a pipe of 22.29 meters high. However, there is no flow in the pipe. Since this pressure balances that of the pump, the piston of the pump does not move. Therefore, we should take a value of the compression height as less than 22.29 meters so that there can be water flowing in the pipe.

The quantity of water which can be compressed into the tank is calculated by taking into consideration the compression height as h = 20 meters and the diameter of the compression pipe as d = 15 cm

In one period, the pump compresses water to the volume of the cylinder.

Cylinder Volume;
V = effective travel length of the piston x S_2 = 70 cm x 1,256 cm^2 = 87,920 cm^3
= 87.92 liter/period = 0.0879 m^3/ 4sec (08)

Q_b = 0.0879/4= 0.0219 m^3/sec (09)

Q= 10 hour x 3,600 sec/hour x 0.0219 m^3/sec = 788.4 m^3/day (10)

If the friction loss is assumed to be 10%: 788.4 - (788.4 x 0.10) = 709.56 m^3/day (11)

Assuming that the establishment of a 20 pontoons of power plant is on a suitable land, the daily use;

Q_{total} = Q x 20 = 709,560 kg x 20 =14,191,200 kg /day (12)

4.3. Energy Calculation

The daily amount of energy stored:

E = H x Q x η (η: efficiency is considered to 0.70) (13)

H = Height of water coming to the turbine, Q= water to be used

E = 20 meters x 14,191,200 x 0.70 = 1.99 x 10^8 kgm (14)

Since 1 kgm = 2.72 x 10^{-6} kWh (15)

E = 1.99 x 10^8 x 2.72 x 10^{-6} = 541 kWh (16)

In the case that 10 hours daily production is made from the water stored throughout the day,

E1 = 541/10 = 54.1 kWh energy can be generated. (17)

4.4. Annual Energy Generation

It is obvious that such a facility would be very productive if installed by the shore of a very windy, high-wave sea for a significant period of the year. In the calculations, the annual number of wavy sea days is assumed to be 180.

In this case, annual energy generation would work out to be

E_y = 180 days x 541 kWh/day = 97,380 kWh/year (18)

The monetary equivalent of the generated energy works out to: 97,380 kWh/year x 0.71TL/kWh = 69,140 TL/year = **8. 64 $/year** (The average price, including taxes on electricity in Turkey) (Çevre ve Şehircilik Bakanlığı, 2019).

Table 2. Hyper-gen cost analysis if installed in a real environment

MATERIAL	COST ($)
24 m2 pontoon manufacturing (3 mm sheet) with all apparatus including labor and installation (20 pieces)	32.000
Suction – compression pump	5.000
Including workmanship and installation with PVC pipe fittings	11.500
Upper tank reinforced concrete	4.000
50 kW Turbine and generator	12.000
Steel construction	5.000
Electrical connection lines and materials	500
TOTAL COST	**70.000**

Table 2 was prepared while taking into consideration the unit price stipulated by the Ministry of Environment and Urbanization 2019 (Çevre ve Şehircilik Bakanlığı, 2019). Break-even Point of Investment Cost / Annual Revenue = 70,000 /8,864 = 7.90 year.

5. Conclusion and Discussion

According to the 2019 data, in Turkey the average daily electricity consumption stands at 7.5 kWh for a family of four. Based on one hundred families, this number stands at 7.5 x 100 = 750 kwh (TSKB Enerji Bülteni, 2020).

Since annual energy production amounts to E_y = 97,380 kWh / year, the energy proposed in this study can meet the 97,380 / 750 = 129.8 days demand of one hundred families.

The average return on energy investments is 10 years. According to the calculations made, the return time of the energy generation model proposed in this study is 7.90 years. In other words, the return on this investment is very reasonable because except for initial costs and maintenance, the investment will be profitable after 8 years. In addition, since this investment produces natural energy, it has no negative impact on the environment. Therefore, if the number of pontoons is increased as well as their sizes, the cost will likely decrease.

In the system we will use in daily life, the lower and upper tanks, the pistons, the gears and the other metal parts will be made of stainless steel. Although the system operates in salt water, no corrosion effect will be observed due to the stainless steel material. It is beneficial to check the system on a monthly basis as wear may occur in the gears over time due to friction. Spare parts will be easily available in the market and will not be economically burdensome since they are low cost.

Acknowledgment and Information

Three sides of our country are surrounded by seas. When wave energy analysis is performed, the Black Sea is found to be the most suitable location for energy harvest.

In this study, according to a detailed wave analysis of the proposed system, it is projected that clean energy can be obtained by installing this system to a province by the Black Sea coast.

The article complies with national and international research and publication ethics. Ethics committee permission was not required for the study.

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