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Harnessing Waves Energy in South Coasts of Iran

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***Abstract*:** *The application of sustainable energy and harnessing natural energies has become one of the most important topics of scientific studies. Studies in the area started early in the 19th century and was intensified due to the reduction of oil reserves. With regard to sustainable energies, durable energies such as wind power, solar energy, tidal energy, geothermal power, and wave energy, which meet the needs of present, are unquestionably considered specifically significant for future generations. The present study attempts to investigate and review the energies produced by hitting the marine waves against the installed turbines on the surface of seas and oceans and recommends the use of such generators at the Bushehr coasts in south of Iran.*

Keywords: *sea waves, sustainable energy, natural energies, turbines*

1. Introduction

The ocean holds a tremendous amount of untapped energy. Although the oil crisis of the 1970s increased interest in ocean energy, relatively few people have heard of it as a viable energy alternative. In fact, hydroelectric dams are the only well known, mass producing water-based energy, but the ocean is also a highly exploitable water-based energy source. This report provides an overview of the energy found in ocean waves, the current state-of-the art in methods used to extract this energy, commercial prospects, and environmental concerns associated with ocean wave energy extraction. There is no single answer to replacing fossil fuelled generation. The world needs a range of different technologies to meet its energy requirements. It is because of this need that more and more emphasis is being placed upon the development of sustainable forms of energy generation. We already have hydro-electricity and growing wind and biomass energy industries but there are other opportunities out there too. Harnessing marine renewable energy, more specifically wave and tidal stream energy is not new but it is only now that we are focusing on making it a reality. Marine renewable energy can provide a significant contribution to our energy needs in the future. We have a huge untapped resource in the oceans and seas, but we need to put in place the technology, infrastructure and support to make best use of this clean inexhaustible energy supply.

- Create a sustainable energy supply – Marine renewable energy is natural and inexhaustible, we will never run out of this clean renewable energy. By harnessing this resource efficiently, we will have a sustainable and environmentally friendly source of power for generations to come.
- Ensure security of energy supply – As competition for fossil fuels increases they will become harder to obtain. Using the marine energy around our own coastline will reduce our dependence on imported fuels.

- Build a new industry – Making marine renewable a reality will require us to establish new technologies, industries and skills that can be exported all over the world. [1]

2. Literature view

Concentrated effort in research of WECs began in 1973 with the onset of the Arab-Israeli war when Arab nations began using oil as a means of applying pressure on the international supporters of Israel. These sanctions became the major driving force behind the need to develop alternative energy sources internationally. [2]

The concept of producing useful energy or work from wave action predates sanctions with the first patent taken out in France in 1799 (Ross, 1995). Utilizing the effect of wave surface motion on a large buoyant object (a ship of the line as stated in the patent) to operate a lever with its fulcrum on the ship, used for lifting, pumping, milling etc. [3]

2.1. Wave Physics and Resource

Among different types of ocean waves, wind generated waves have the highest energy concentration. Wind waves are derived from the winds as they blow across the oceans (Figure 1.). This energy transfer provides a natural storage of wind energy in the water near the free surface. Once created, wind waves can travel thousands of kilometers with little energy losses, unless they encounter head winds. Nearer the coastline the wave energy intensity decreases due to interaction with the seabed. [4]

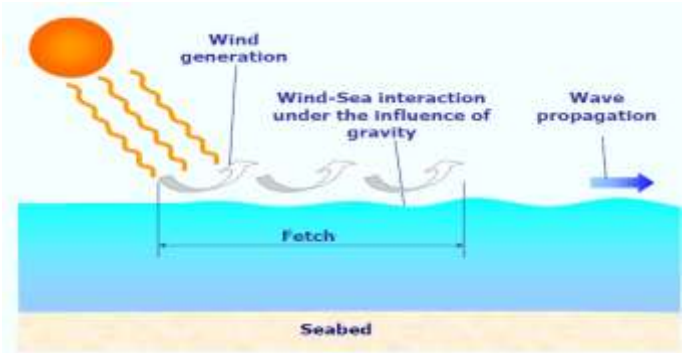


Fig. 1: Generation of waves [4]

3. Wave energy

Ocean waves encompass two forms of energy: the kinetic energy of the water particles that in general follow circular paths; and the potential energy of elevated water particles (Figure 3.). On the average, the kinetic energy in a linear wave equals its potential energy. The energy flux in a wave is proportional to the square of the amplitude and to the period of the motion. The average power in long period, large amplitude waves commonly exceeds 40-50 kW per meter width of oncoming wave. [4]

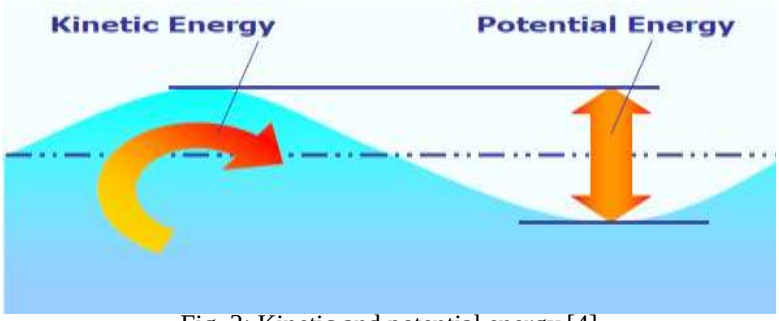


Fig. 3: Kinetic and potential energy [4]

3.1. Wave power distribution

Wave energy is a viable energy option on the coastlines of Iran because of the length of the country's coastline, the proximity of the national electrical grid to these areas, the power potentially available in the waves on this coastline (Figure 4.) and the low variability in the wave climate. [4]

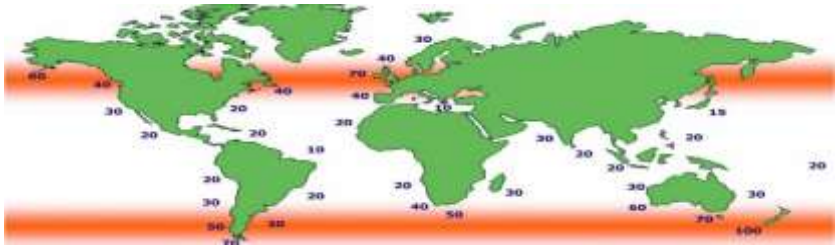


Fig. 4: The distribution of annual wave power in kW/m wave crest (Thorpe, 1999).

3.2. Wave energy devices work

Wave power devices are generally categorized by the method used to capture the energy of the waves. They can also be categorized by location and power take-off system. Method types are point absorber or buoy; surfacing following or attenuator oriented parallel to the direction of wave propagation; terminator, oriented perpendicular to the direction of wave propagation; oscillating water column; and overtopping. Locations are shoreline, near shore and offshore. In (Table1.) there are some types of devices and their functions as a energy grabber. Types of power take-off include: hydraulic ram, elastomeric hose pump, pump-to-shore, hydroelectric turbine, air turbine, and linear electrical generator. Some of these designs incorporate parabolic reflectors as a means of increasing the wave energy at the point of capture. These capture systems use the rise and fall motion of waves to capture energy. Once the wave energy is captured at a wave source, power must be carried to the point of use or to a connection to the electrical grid by transmission power cables.

3.3. Wave power formula

In deep water where the water depth is larger than half the wavelength, the wave energy flux is

$$p = \frac{\rho g}{64\pi} H_{m0}^2 T \approx \left(0.5\ \frac{KW}{m^3 . s}\right) H_{m0}^2 T$$

With P the wave energy flux per unit of wave-crest length, Hm0 the significant wave height, T the wave period, ρ the water density and g the acceleration by gravity. The above formula states that wave power is proportional to the wave period and to the square of the wave height. When the significant wave height is given in meters, and the wave period in seconds, the result is the wave power in kilowatts (kW) per meter of wavefront length.[5][6]

3.4. Wave energy and wave energy flux

In a sea state, the average energy density per unit area of gravity waves on the water surface is proportional to the wave height squared, according to linear wave theory: [7]

$$E = \frac{1}{16} \rho g H_{m0}^2$$

Where (E)is the mean wave energy density per unit horizontal area (J/m2), the sum of kinetic and potential energy density per unit horizontal area. The potential energy density is equal to the kinetic energy, both contributing half to the wave energy density E, as can be expected from the equipartition theorem. In ocean waves, surface tension effects are negligible for wavelengths above a few decimeters.[8]

4. Iran Renewable energy

The Islamic Republic of Iran is situated in the southwestern part of Asia and the far eastern part of the Middle East. The Caspian Sea is in the north and in the south, the Persian Gulf and the sea of Oman, connects the country to the Indian Ocean and international waterways.

4.1. Iran Energy resources

Consist of the third largest oil reserves and the second largest natural gas reserves in the world.[9] Iran is in a constant battle to use its energy resources more effectively in the face of subsidization and the need for technological advances in energy exploration and production. Energy wastage in Iran amounts to six or seven billion dollars (2008). The energy consumption in the country is extraordinarily higher than international standards.Iran recycles 28 percent of its used oil and gas whereas the figure for certain countries stands at 60 percent. Iran paid $84 billion in subsidies for oil, gas and electricity in 2008.Iran is one of the most energy intensive countries of the world with per capita energy consumption (Figure5.) 15 times that of Japan and 10 times that of EU. Also due to huge energy subsidies, Iran is one of the most energy inefficient countries of the world, with the energy intensity three times higher than global average and 2.5 times the middle eastern average.[10]

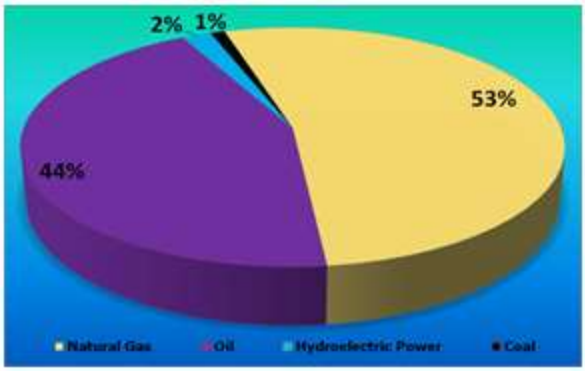


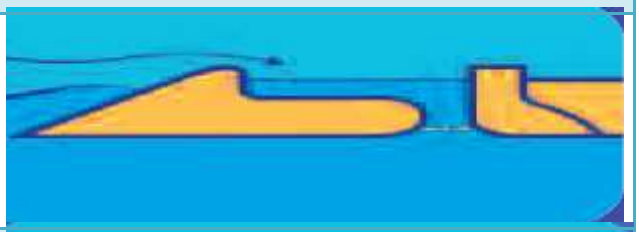
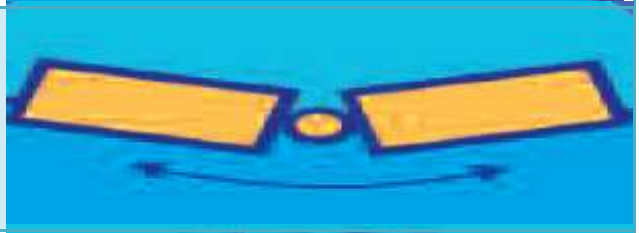
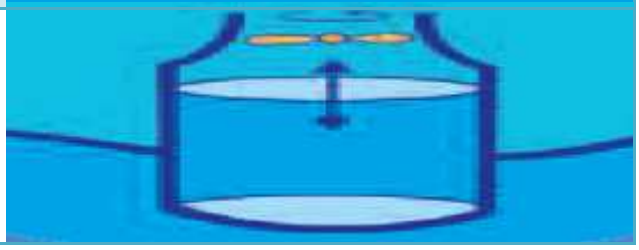
Fig. 5: Total Energy Consumption in Iran, by Type

4.2. Electricity

Iran's domestic consumption (Consumption: 153.8 billion kWh (2009)) and production (Production: 192.6 billion kWh (2009)) have steadily grown together since 1984 and it is still heavily reliant on traditional thermal energy sources of electricity, with a small fraction being produced by hydroelectric plants.[11] Consumption has steadily risen and it is expected to rise at about 6 percent per year for the following decade. Accordingly, the Iranian energy sector must focus its efforts on meeting this continuing demand. Today Iran ranks 19th largest producer and 20th largest consumer of electricity in the world.[9]

We can see that the other resources in Iran are not common, as we concentrate on sources we see two primary resources have been used (Figure6.). And this is the time to begin a new era with sustainable energies.

TABLE I: Wave power devices

Device function	Figure
Waveroller A WaveRoller device is a plate anchored on the sea bottom by its lower part. The back and forth movement of bottom waves moves the plate, and the kinetic energy produced is collected by a piston pump. This energy can be converted to electricity by a closed hydraulic system in combination with a hydraulic motor/generator system	
Buoys A floating structure is forced to move by waves which can move up and down or side to side. This motion can be used to produce power.	
Terminators A long line of floating structures are placed in the sea. As the waves arrive at one side of this line they cause the floats to move against each other, producing power.	
Overtopping A floating pool is placed in the sea. As waves arrive they are forced upover a ramp into the pool. The water then flows back into the sea through a turbine to produce power.	
Surface following Several floating structures are hinged together and follow the surface of the sea. The motion of the structures against each other produces power.	
Oscillating water columns A column of water is held in a tube. One end of the tube is open to the sea, the other open to the air. The waves make the water column move up and down. This in turn forces air back and forth through an air turbine to produce power.	

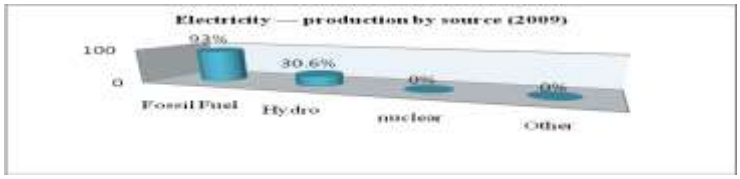


Fig. 6: Iran Electricity production by source [10]

4.3. Bushehr Coast

Bushehr, a city in south west of Iran, located on the Persian Gulf, with 60 kilometers sea border. Its location is 28° 59' N, 50° 49' E, about 1,281 kilometers (796 mi) south of Tehran. The local climate is hot and humid.

With analyzing the wave height on Bushehr Coast during different times on a day in a month(table 2. & Figure 7.) we measured the energy that generated with waves.

TABLE II: Wave height based on different times in a day on January 2010 (Bushehr Coast)

Jan.		Time	H (m)	Time	H(m)	Time	H(m)	Time	H(m)
1	*Fri*	*03:17*	*0.16*	*09:59*	*1.12*	*13:26*	*0.94*	*19:59*	*2.26*
2	*Sat*	*03:53*	*0.13*	*10:30*	*1.19*	*14:25*	*0.89*	*19:59*	*2.24*
3	*Sun*	*04:28*	*0.14*	*11:02*	*1.26*	*15:20*	*0.85*	*20:47*	*2.16*
4	*Mon*	*05:02*	*0.18*	*11:37*	*1.36*	*16:14*	*0.84*	*21:33*	*2.02*
5	*Tue*	*05:35*	*0.25*	*12:15*	*1.47*	*17:11*	*0.85*	*22:19*	*1.82*
6	*Wed*	*06:08*	*0.33*	*12:56*	*1.58*	*18:13*	*0.87*	*23:04*	*1.59*
7	*Thr*	*06:40*	*0.44*	*13:39*	*1.69*	*19:27*	*0.89*	*23:50*	*1.63*
8	*Fri*	*00:41*	*1.34*	*07:11*	*0.58*	*14:25*	*1.79*	*22:58*	*0.86*
9	*Sat*	*01:49*	*1.09*	*07:40*	*0.69*	*15:13*	*1.87*	*21:11*	*0.74*
10	*Sun*	*03:59*	*0.9*	*08:04*	*0.81*	*16:03*	*1.92*	*23:18*	*0.98*
11	*Mon*	*00:43*	*0.57*	*16:55*	*1.95*	*16:20*	*1.96*	*23:40*	*1.05*
12	*Tue*	*01:37*	*0.44*	*17:47*	*196*	*16:40*	*1.98*	*23:53*	*1.56*
13	*Wed*	*02:18*	*0.36*	*09:33*	*1.36*	*11:19*	*1.4*	*23:59*	*1.97*
14	*Thr*	*02:51*	*0.31*	*09:44*	*1.11*	*12:34*	*1.3*	*18:35*	*1.97*
15	*Fri*	*03:19*	*0.3*	*09:59*	*1.16*	*13:29*	*0.99*	*19:19*	*1.96*
16	*Sat*	*03:43*	*0.3*	*10:17*	*1.21*	*14:14*	*0.94*	*19:57*	*1.94*
17	*Sun*	*04:05*	*0.32*	*10:37*	*1.26*	*14:55*	*0.9*	*20:32*	*1.9*
18	*Mon*	*04:27*	*0.33*	*10:58*	*1.31*	*15:33*	*0.87*	*21:04*	*1.84*
19	*Tue*	*04:47*	*0.35*	*11:20*	*1.37*	*16:12*	*0.87*	*21:35*	*1.75*
20	*Wed*	*05:08*	*0.38*	*11:44*	*1.44*	*16:51*	*0.87*	*22:06*	*1.63*
21	*Thr*	*06:30*	*0.42*	*12:09*	*1.52*	*17:35*	*0.89*	*22:36*	*1.48*
22	*Fri*	*00:50*	*0.48*	*12:39*	*1.61*	*18:27*	*0.91*	*23:07*	*1.31*
23	*Sat*	*01:10*	*0.55*	*13:14*	*1.69*	*19:37*	*0.91*	*21:41*	*1.46*
24	*Sun*	*00:21*	*1.11*	*06:27*	*0.63*	*13:58*	*1.87*	*21:42*	*1.67*
25	*Mon*	*01:32*	*0.91*	*06:32*	*0.72*	*14:51*	*1.86*	*21:39*	*1.36*
26	*Tue*	*01:09*	*0.91*	*15:57*	*1.94*	*13:47*	*1.63*	*21:00*	*2.09*
27	*Wed*	*02:03*	*0.49*	*16:57*	*2.02*	*14:26*	*1.58*	*21:20*	*2.15*
28	*Thr*	*02:43*	*0.34*	*08:57*	*0.97*	*10:42*	*0.96*	*18:02*	*1.16*
29	*Fri*	*03:19*	*0.23*	*09:03*	*1.05*	*12:17*	*0.91*	*19:03*	*2.11*
30	*Sat*	*02:53*	*0.17*	*09:25*	*1.15*	*13:28*	*0.81*	*19:59*	*2.2*
31	*Sun*	*03:25*	*0.18*	*09:52*	*1.27*	*14:27*	*0.72*	*20:49*	*2.29*

Consider moderate sea swells, in deep water, a few kilometers off a coastline, with a wave height of 2.2 meters and a wave period of 2.5 seconds. Using the formula to solve for power, we get

$$p = 0.5\frac{KW}{m^3.s}(2.2m)^2(2.5.s) \approx 5.3\frac{KW}{m}$$

Meaning there are 5.3 kilowatts of power potential per meter of coastline. An effective wave power device captures as much as possible of the wave energy flux. As a result the waves will be of lower height in the region behind the wave power device.

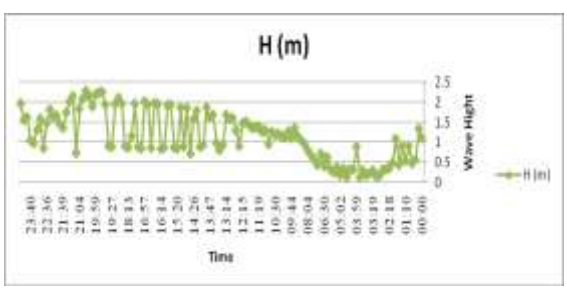


Fig. 7: Wave height based on different times in a day on January 2010 (Bushehr Coast)

The coast line of Persian Golf is 1259km and coastline of Oman Sea is 784km, then overall coastline is about 2043km. If because of the situation of region we could use only 30 % of these coastlines, then we have approximately 600km of coastline. With the energy of 5.3 $\frac{KW}{m}$ we get to this: $600km \times 1000m \times 5.3 = 3180000KW = 3180MW$

According to the data from Iranian Ministry of Electricity, current year's electricity production has passed 168,654 Megawatts.

$$\frac{Wave\ generated\ power}{Production} = \frac{3180MW}{168654\ MW} = 1.88\%$$

This means we could produce approximately 2% of electricity demand by clean energy.further coaprations are needed to increase this amount of energy.

5. Conclusion

Lack of finances, poor installation and lack of maintenance are the major hindrances to the ongoing adoption of RET (Renewable Energy Technologies) in Iran. Any co-operation between international and local institutions is bound to produce productive results because international institutions have developed proven expertise in various RETs. They have also built an enormous level of experience in dealing with RE financing and implementation. The international institutions have ISO 9001 and ISO 14000 registrations that assure the quality that assure the quality and environmental responsibility that the Islamic Republic of Iran requires. The government of Iran could put in place programs that would complement and strengthen RE enterprises by initiating internal reforms that would involve private sector participation. Therefore, RETs offer huge opportunities for social and economic development of Iran. Another critical aspect is the integration of RE courses into a regular training curriculum to tertiary and higher educational institutions at the local, regional and national level within Iran. So Iran needs radical changes in energy sector policies in order to move to harmoniously joint thinking, policymaking and action. The biggest change required is to place environmental objectives at the top of global, national, and personal priorities. This shift definitively does not mean ignoring country's basic needs satisfaction, or its economic and social advancement. But satisfaction of Iran's objectives must be made compatible with environmental goals. This means far greater transfers of financial resources, technology and know-how from industrialized countries to developing ones for environmentally friendly progress. [12]

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