Technologies for Clean and Renewable Energy Production
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Lecture - 34
Tidal and Wave Energy

Hi friends, now we will start discussion on the topic tidal energy. Like wind, the tides and waves can also be used for the production of electricity.

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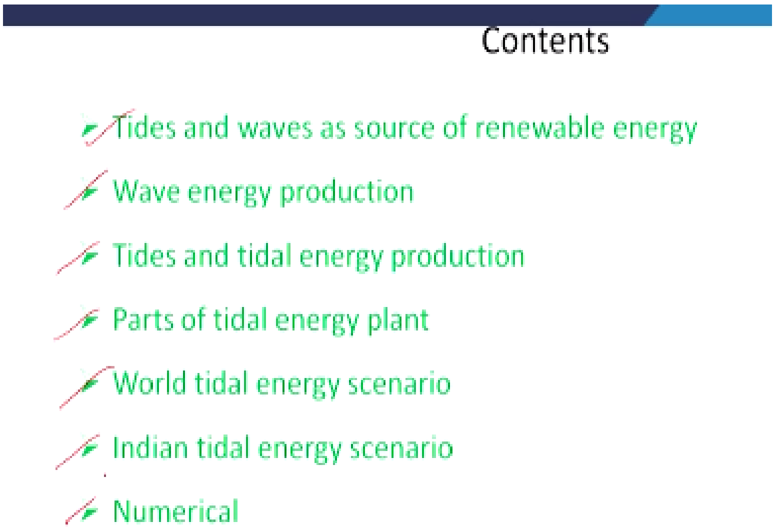

And in this class, we will discuss on tides and waves as source of renewable energy, wave energy production, tides and tidal energy production, parts of tidal energy plant or type of tidal energy plant, world tidal energy scenario, Indian tidal energy scenario, and one numerical. So we will see what waves are and what are tides are and how this can be the source of renewable energy first.

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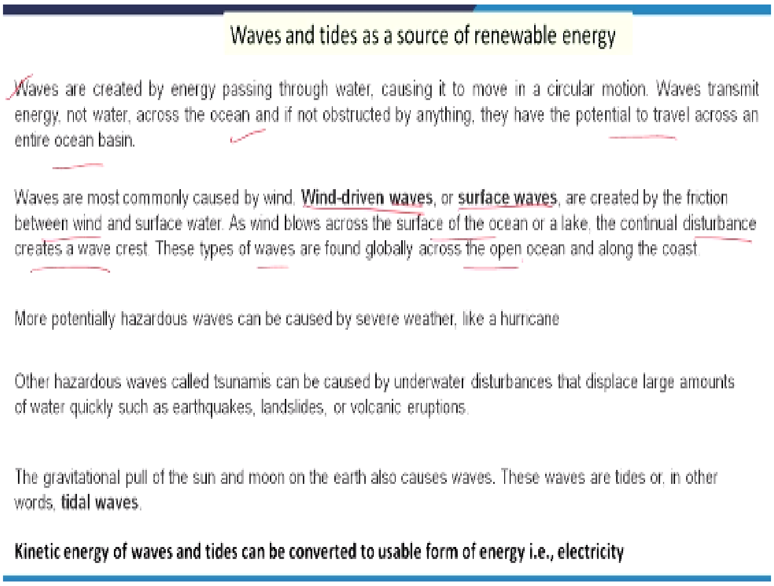

As you know, the waves are created by energy passing through water causing it to move in a circular motion. Waves transmit energy, not water, and across the ocean and if not obstructed by anything, they have the potential to travel across an entire ocean basin. So if we see the nature of waves, wave maybe of different types. So one is wind driven waves or surface waves.

So these waves are basically generated due to the friction between the wind and surface water, so friction between wind and surface water makes the wave that is called surface wave or it is wind driven waves. As the wind blows across the surface of the ocean or a lake, the continual disturbance creates a wave crest. These types of waves are found globally across the open ocean and along the coast.

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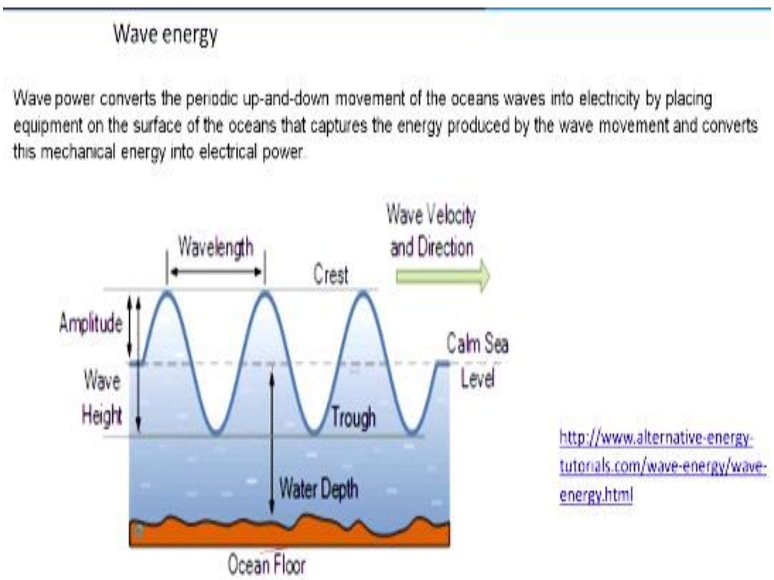

So this is the wave crest. So here the water, there is some up and down at the surface, so this is our calm sea level and sometimes we get up and sometimes down. So this is our amplitude, this is wave height and this is our trough, this is water depth from the ocean floor, this is the depth of the water, this is wavelength and this is the crest which is generated in the wave. This wave is surface wave, but more potentially hazardous wave, that is hurricane. So this is hazardous in nature, it can cause severe consequences or severe weather.

Other hazardous waves like say tsunamis that can be caused by underwater disturbances that displace large amounts of water quickly such as earth quakes, landslides, and volcanic eruptions. So when earth quakes or landslides or volcanic eruption takes place, then large amount of water displacement takes place and which creates the tsunami, so that is very severe or very very dangerous of types of waves. Apart from these due to the movement of earth and the sun and movement of moon around the earth, there is an attraction and gravitational pull of the sun and moon on the earth that causes waves.

These waves are tides or in other words tidal waves. So these tidal waves or any other type of waves surface waves both can be used for the production of electricity and that part we will discuss now. So this is the wave we have explained that when wave up and down movement of the water which we are having, so that movement can be converted to circulatory movement and which can be used for the production of electricity by using some device, so that is the mechanism for the production of wave energy.

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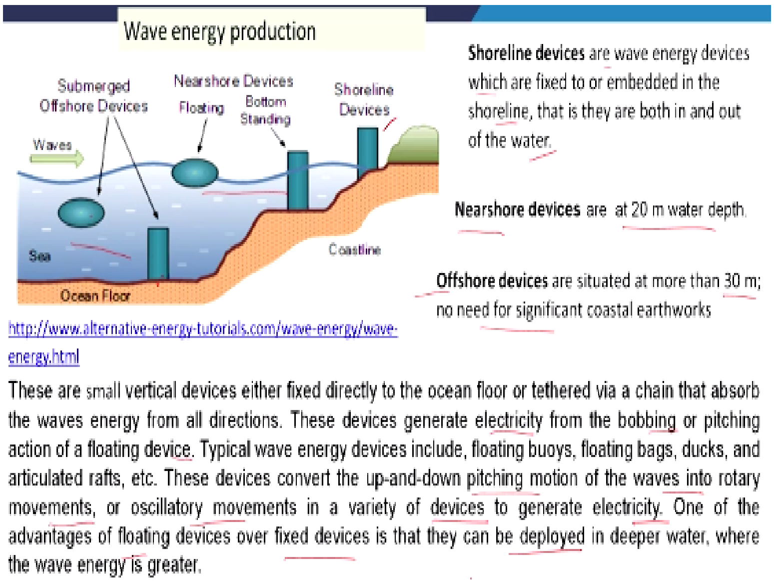

So wave energy production we use some device that helps the conversion of the energy of the wave to electricity. So different types of devices are available, one is your shoreline devices and near shore devices as shown here and these are submerged offshore devices. So shoreline devices half is in the water and half is above the water, some part of it is submerge and some part is above it and these are the shorelines. These 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.

Here near shore devices are at 20 metre water depth and offshore devices it is more than 30 metre water depth and in this case no need for significant costal earthworks. So here, we have ocean floor, another is your floating. So floating device we have another it may be of fixed type. So if we see, these devices are small vertical devices, either fixed directly to the ocean floor or tethered via a chain that absorbs the wave synergy from all directions. These devices generate electricity from the bobbing and pitching action of floating device.

So this floating device which is going up and down bobbing and pitching action, so that action is converted to circulatory movement of another device, convert the up and down pitching motion of the waves into rotary movements or oscillatory movements in a variety of devices to generate electricity. So one of the advantage of floating device with respect to fixed device is that they can be deployed in deep water where more wave energy is available.

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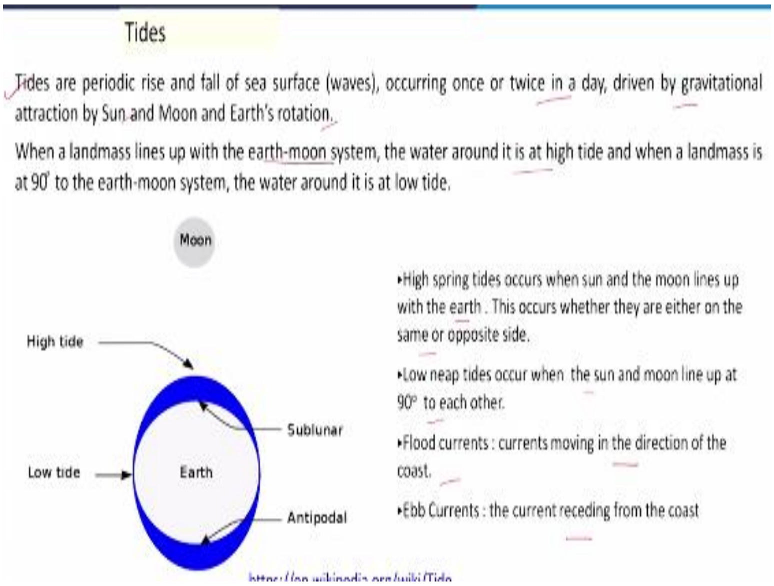

Now we will see the tides. So this figure shows us that the water level in some places increases where in some other places water level decreases on the surface of the earth because of the attraction between the moon, sun and earth. So the tides are periodic rise and fall of sea surface occurring once or twice in a day, driven by gravitational attraction by sun and moon and earth's rotation that we know very well.

Then when a landmass lines up with the earth-moon system, the water around it is at high tide, so here the high tide we can get, the moon and earth and sun will be in one and opposite direction, and on the 90 degree angle of that none of the landmass if it is available, then that will be a low tide, that the surface of the water level will be lower. So when we are getting two high tide and low tide, then the seawater when it rises then water from the river comes back and when the sea water reduces, the water goes towards the river and lakes.

So then high spring tides occurs when sun and the moon lines up with earth, this occurs whether they are either on the same or opposite side, so that is your high tide. Low or neap tides occur when the sun and moon line up to 90 degree to each other and flood currents because of these 2 situations, you get some current of water, so there is flood currents, we get the currents moving in the direction of the coast. Ebb currents the current receding from the coast. So these are the basic definitions of the tides and water currents.

Then we will see the tidal energy. So when the water we have 2 tides, so when the flood current it is going, water is going towards coast and in the other case the coastal water is coming towards the sea in case of ebb current, so in both cases we are getting the kinetic energy of the water, so that like wind energy, we can convert these kinetic energy of water into electricity by the use of the turbine. So that is the basic principal of the tidal energy production.

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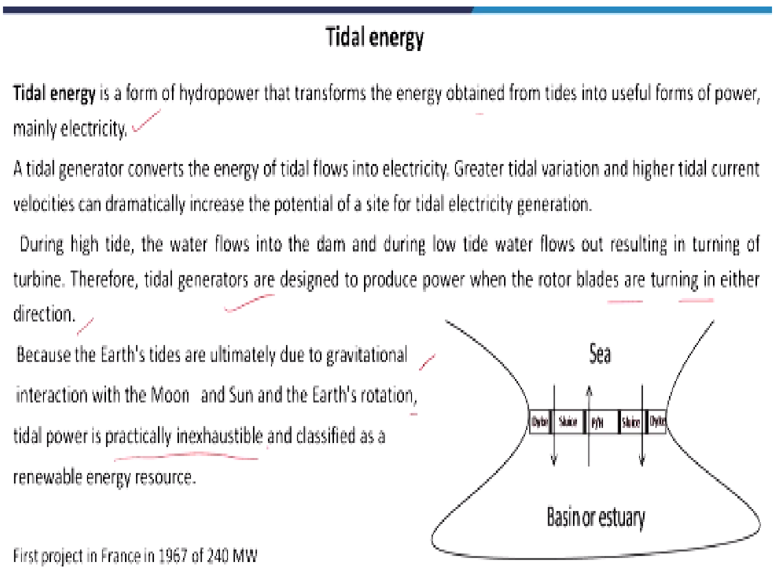

So here tidal energy in the form of hydropower that transforms the energy obtained from the tides into useful forms of power, mainly electricity okay. So we need one turbine, we need one generator, and then we need to store the water which is going to the coast during flood current and also when the water is going down towards the sea during a current, then also the turbines can be used to get the electricity, but unlike here, these turbines will be able to generate electricity in both directions.

Whenever our water is going from the coast to the sea or sea to the coast, so that we have to make. So tidal generators are designed to produce power when the rotor blades are turning in either direction, so rotor blades standing in either directions, our generator will be able to produce electricity in both the cases, so that is the main difference between the wind turbine and this tidal turbines.

Because the earth's tides are ultimately due to gravitational interactions with the moon and sun and the earth's rotation, the tidal power is practically inexhaustible and classified as the renewable energy resources.

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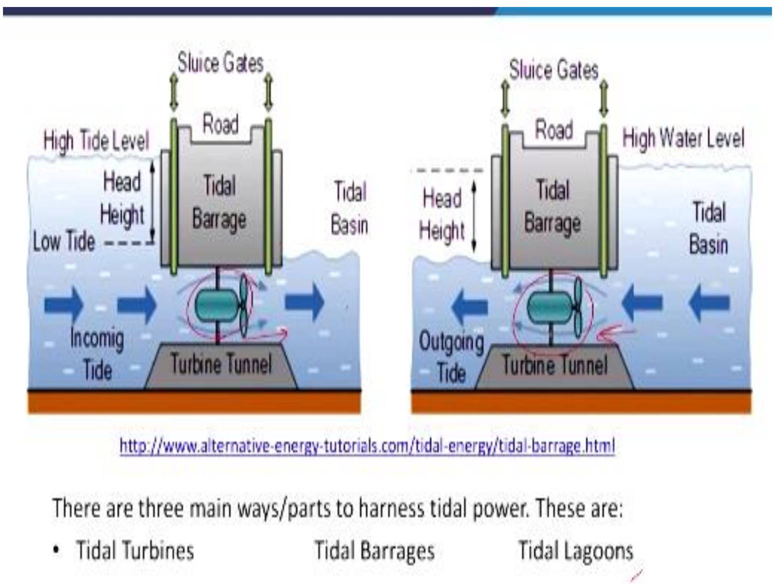

Here we see so high tide level, sea level is very high, so water will go through this if we have tidal machine. So we can make one barrage here, so this turbine will be used for the production of electricity. Other case when there is high water level here at a tidal basin, then again water will move this direction, here water moving that direction here water is moving this direction and this turbine is able to work continuously and to give electricity.

So now what are the parts of these types of these system for the production of electricity? So one is we need the turbine a very essential part of it, then we need tidal barrage or it may be tidal lagoons. So this water which is going to the coast we have to store it, we can make a barrage or that can be stored in lagoons also. So these are the basic parts of the types of the tidal energy production units and most important is our turbines, so tidal turbines.

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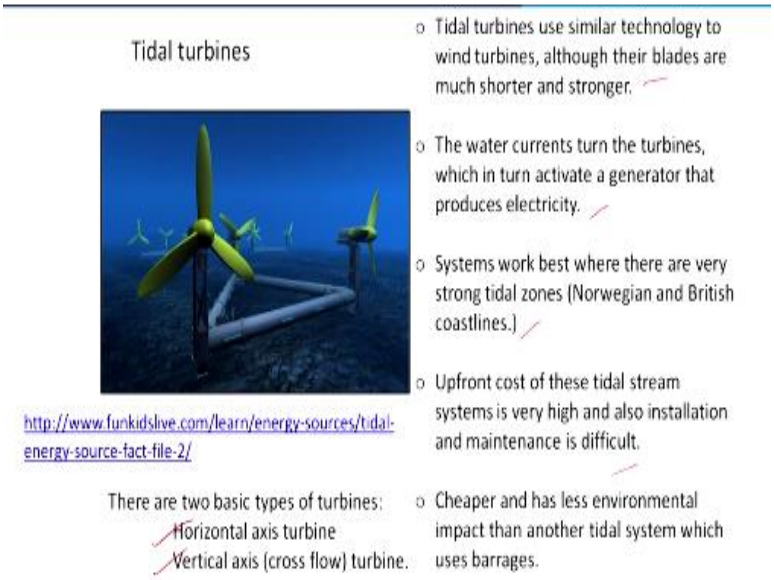

So here we see the turbines first. So tidal turbines are just like wind turbines, so in case of wind, we had used air and the kinetic energy of air for the production of mechanical energy of the of the turbine shaft and then that mechanical electrical energy, here the kinetic energy of water will be used to get the mechanical energy in the turbine shaft and that will be converted to electricity. So the density of water is higher with respect to the wind.

So in this case, the turbine blade requirement is not that big, so we need smaller blades with respect to wind turbine in case of tidal turbines. So the title turbines use similar technology to wind turbines, although their blades are much shorter and stronger. The water currents turn the turbines which in turn activate a generator that produces electricity, just like the concept of wind energy production.

Systems work best where there are very strong tidal zones obviously and upfront cost of these tidal stream systems is very high and also installations and maintenance is difficult. There are basically 2 types of turbines, one is your horizontal axis and vertical axis, just like wind turbines, the horizontal axis and vertical axis.

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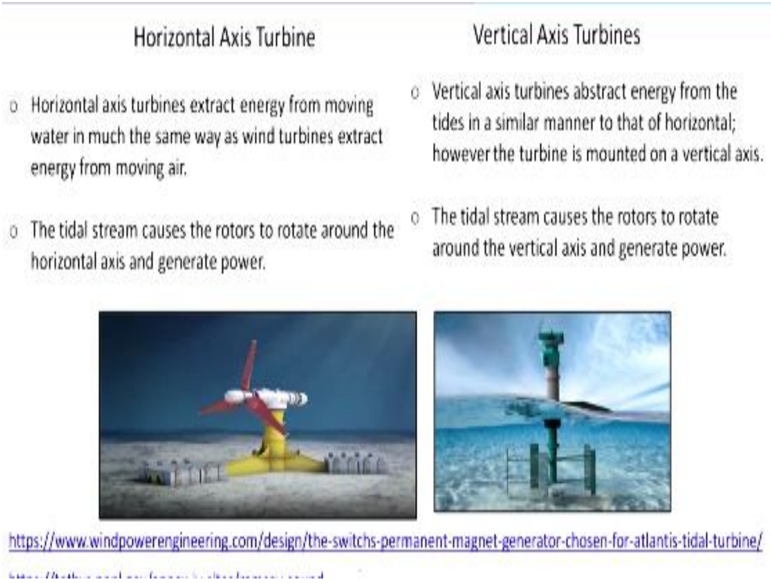

So here we see the horizontal axis and here we see the vertical axis of the turbine blade, rotor is horizontal, here it is vertical. So the rotors and blades are similar type of the wind we have discussed in our wind turbine section, so we are not making detailed discussion here, the similar types of rotor design and configurations are available.

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Then tidal fences, tidal fences is also used, one type of design which is used for the harnessing of tidal energy. So this is other forms of tidal energy include tidal fence which use individual vertical axis turbines that are mounted within a fence structure, here vertical axis turbine, so these are the fence and we have used the turbines. The water will be forced to go through this gate and then the turbine will on. So that is the mechanism of tidal fence.

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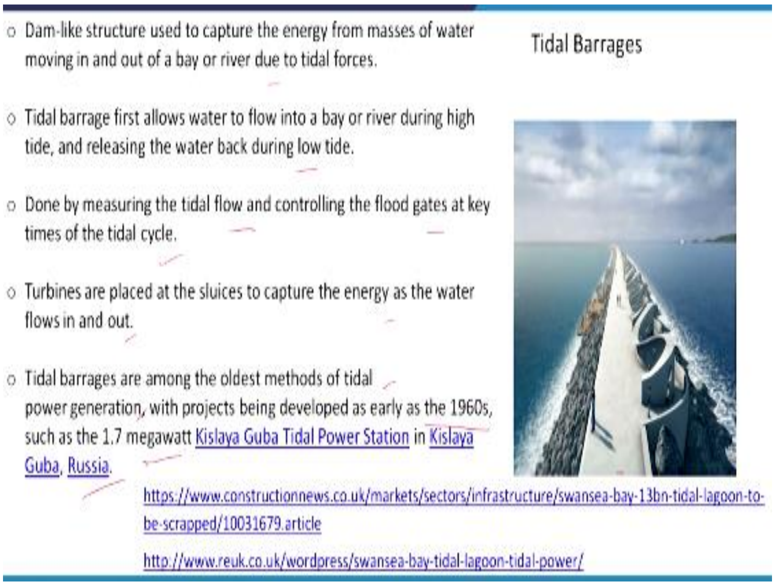

Then tidal barrage, we see here the tidal barrage the figure shows. So dam like structure used to capture the energy from masses of water moving in and out of a bay or river due to tidal forces. So this is the photograph here, it is shown. The tidal barrage first allows water to flow into a bay or river during high tide and releasing the water back during low tide. So done by measuring the tidal flow and controlling the flood gates at key times of the tidal cycle, so in the tidal cycle, we have to control the flood gates.

Turbines are placed at the sluices to capture the energy as the water flows in and out. Tidal barrages are among the oldest methods of tidal power generation with projects being developed as early as 1960s, I think that was in Russia, the 1.7 megawatt energy were produced.

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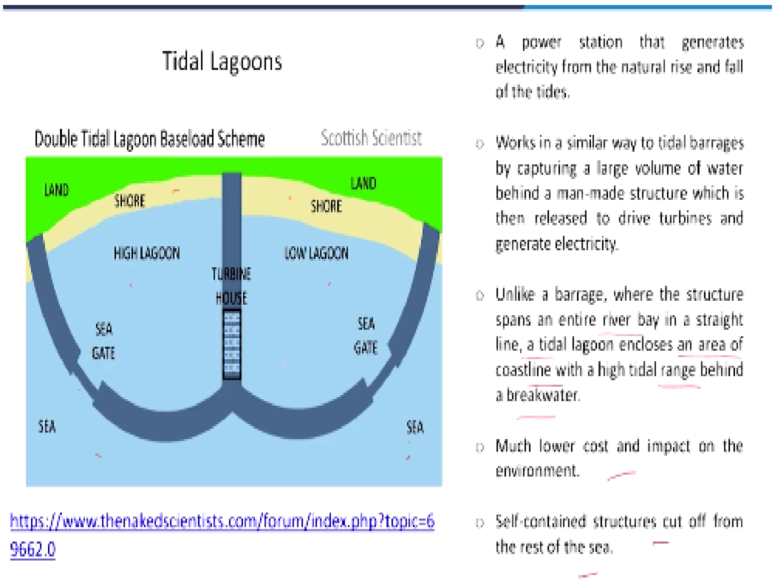

Then another is tidal lagoons if you see, so here we have land, this is our shore and this is our sea. So from sea, there are some part is separated, so these are the sea gate, through gate water will go in this lagoon and there are some turbine house. So turbine house from here both sides, so high lagoon, low lagoon, so water will go here and then the turbines will be working.

So here a power station, this is a power station that generates electricity from the natural rise and fall of the tides, that works in a similar way to tidal barrages by capturing a large volume of water behind a man made structure as shown here which is then released to drive turbines and generate electricity. Unlike a barrage where the structure spans an entire river bay in a straight line, a tidal lagoon encloses an area of coastline with a high tidal range behind a breakwater, so this is not a very lengthy structure, it is a confined structure here.

Much lower cost and impact on the environment. Self-contained structures, cut off from the rest of the sea. So these are the advantage of the tidal lagoons with respect to the title barrage.

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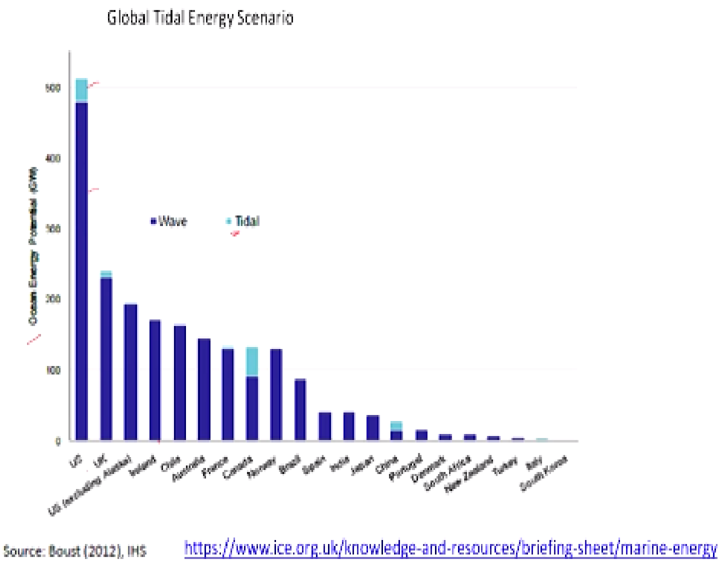

Now we will see the global tidal energy scenario. So different countries and their ocean energy production tidal energy production capacity is given in gigawatt. So you see the US on the top. Wave and this is our tide, this color is for tide and this is for wave. So then UK and we are here in India, we have wave energy we do not have any tidal energy yet. So these are the other countries where the tidal energy or sea energy is being used, the energy from the sea is converted to electricity.

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Now this one example, the Sihwa Lake Tidal Power Station that is 254 megawatt in South Korea is the world's largest tidal power station, the largest tidal power installation is Sihwa Lake and the figure is shown here. So this tidal power is not yet widely used around the world though it has potential for future electricity generation. Among sources of renewable energy, tidal power has relatively high cost and limited availability of sites with sufficiently high tidal ranges or current velocity.

So hydro electricity power plant operation height of the water is very very important, but in many cases we do not get that sufficient height, so if we do not get the water height, so then the turbine efficiency will also not be that high, the electricity production will not also not be high. So those are some major drawbacks for which this energy production is not taking place widely around the world.

But many technological developments and improvements both in design that is dynamic tidal power, tidal lagoons and say turbine technology, new axial turbines and cross flow turbines, etc that indicate that the total availability of tidal power may be much higher than previously assumed. So what are the tidal energy available today that can be increased, availability can in increased by the improvement in the design of the turbine or if we increase the design of the water reservoir such though we can get sufficient height so that way also can be done.

So this Sihwa Lake Tidal Power Plant, the largest one in the world, and mean operating tidal range here is 5.6 metre with a spring tidal of 7.8 metre.

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Indian Tidal energy scenario

- India has a long coastline with the estuaries and gulfs where tides are strong enough to move turbines for electrical power generation.
- India has been looking at generating electricity via tidal power since the 1980s.

	Maximum (m)	Average (m)	Potential (MW)
Gulf of Cambay, Gujarat	11	6.77	7000
Gulf of Kachh , Gujarat	8	5.23	1200
Sundarban, West Bengal	5	2.97	< 100

- Projects which were planned earlier were abandoned due to high capital costs.
- India needs to consider factors like the environmental impact of these projects on the ecosystem,
- A strong tidal energy policy to attract investors to projects.

Indian tidal energy scenario if we see, then we have good potential that is Gulf of Cambay and Gulf of Kachh and Sundarban. So these are the 3 major areas where the availability of tidal energy is very high. So here you see the height is maximum 11 metre, here 8, here 5 and average 6.77, 5.23 and 2.97. So here the Gulf of Kachh and Gulf of Cambay this have height is very high with respect to the Sihwa lake which is 5.6 to 7.8 metre, we are also having 6.77 and 5.23, very comparable height and our potential is also very high 7000, 1200, and in case of Sundarban as the height is less we see here the potential is also less.

So India has a long coastline with the estuaries and gulfs where tides are strong enough to move turbines for electrical power generation. India has been looking at generating electricity via tidal power since 1980s. Projects which are planned earlier were abandoned due to high capital cost, the cost factor is one major issue for not getting success for this option for energy production, but India needs to consider factors like the environmental impact of these projects and the ecosystem and a strong tidal energy policy to attract investors to project.

So if some cost effectiveness can be improved by research or some development, then this technology can be of interesting future.

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Numerical

Determine the quantity of heat generated due to breaking to stop a goods train consisting of 50 wagons and traveling at a speed of 36 km/h. The average weight of each wagon is 20 tonf Calculate the time required to produce the equivalent amount of electric energy by a small tidal power plant of 15 kW capacity.

The weight of goods train = 50*20000 kgf

The mass of goods train = 50 *20000/9.81 kgf.sec^2/m = 102000 kgf sec^2/m

Speed of goods train = 36 km/h = 10 m/sec

Kinetic energy of the goods train = ½ * 102000*(10)^2 = 5.1*10^6 kgfm = 5.1*10^6/367098 = 13.9 kWh

[1 kWh = 367098 kgfm]

The capacity of the small tidal power plant = 15 kW

Thus, time required to produce equivalent electric energy = 13.9/15 h = 0.926 h = 56 min

A numerical is given here. So determine the quantity of heat generated due to breaking to stop a goods train consisting of 50 wagons and travelling at a speed of 36 kilometer per hour. The average weight of each wagon is 20 ton force. Calculate the time required to produce the equivalent amount of electric energy by a small tidal power plant or 15 kilowatt capacity. So the statement is very simple just to energy balance, so what is said here that a goods train is running with 50 wagons and each wagon is having a say 20 ton force.

So if you want to stop the goods train, then huge amount of heat will be generated, and if that amount of energy if we want to produce from a tidal power plant which is having the 15,000 watt capacity, then we have to calculate the time required for the production of this amount of energy by this plant. So we will be doing the energy balance. So the weight of the goods train so we have 50 wagons, so 50 x 20 tons, so 20 x 1000 kgf, so this kilo force this is the weight of the wagon, and the mass of goods train is equal to this weight into divided by G.

So that is equal to kilo force into second square per metre, so this is equal to this one kilo force into second square per metre. So speed of goods train is given equal to or velocity is given equal to 36 kilometer per hour that is equal to 10 metre per second. So kinetic energy of the goods train is equal to 1/2 mv square now, so 1/2 x this one equal to 5.1 x 10 to the power 6 kilo kg force metre, that is (5.1 x 10 to the power 6)/367098 because we know 1 kilowatt hour is equal to 367098 kg force metre, so then it is giving 13.9 kilowatt hour.

We have 15 kilowatt capacity, so what will be the time requirement. We will be getting 13.9/15 that will be in hour unit, so that is 0.926 hour that is equal to 56 minute. So 56 minute is required for this plant to produce that amount of energy which is generated due to the breaking of a goods train having 50 wagons and mass of 20 ton and moving with the speed of 36 kilometers per hour. So, up to this in this class. Thank you very much for your patience.