Non-conventional Energy Resources
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Lecture – 20
Wind Energy: Overview

Hello there, last several classes we have been discussing solar energy in considerable detail, we looked at solar energy in various ways we could use it photo-thermal, photovoltaic and photo-catalysis. Those were the three major ways in which we considered using it. So, we sort of, that was the extent of the discussion we wanted have on solar energy. The new topic we start on today is on wind energy. This is the other major way in which we are trying to you know use renewable source of energy for applications in the human context.

Now, I must also tell you that you know something that we discussed right in one of our early classes that even though there is so much effort in all these directions in solar energy in terms of windmill etcetera, the real penetration they have made so far into the overall global scheme of things is still quite low. I mean we are still looking only at 1, 2, 3 percent you know a small percentage of you know penetration of these kinds of technologies into the actual supply process which is what is supplying you know our electricity to our homes, to our offices, to our workplaces and so on. So, there is still a long way to go, but still given the various options that are available solar energy is considered extremely clean, wind energy is also considered extremely clean.

In a sense, the wind energy is a different way in which we are capturing the solar energy. as you are aware the you know sunlight comes down on us and heats up the earth and it is not uniform. We have you know heating at various places occurring to differing degrees. So, there is temperature difference across the planet, may be minor temperature differences, but still significant enough temperature differences. So, we have you know the entire weather system is fueled by this energy that comes in from the sun. So, if we had absolutely no energy from the sun and we had you know we were it was a cold place everything would be rather relatively quiet, because we have this daily incoming energy from the sun and the fact that the earth rotates and so many other things factors which contribute to each other in this manner. We have a very active weather system. We have

a lot of you know movement of clouds, you have lot of evaporation, cloud formation, movement of clouds, rain, you have wind movement, you have movement of water, a lot of stuff is happening on the planet as a direct result of the sunlight that is coming in on us every day.

So, in some ways as I said the wind energy it is an indirect way in which we are using the solar energy because that is what is causing the wind to begin with. And this itself constitutes only about say 1 or 2 percent of the solar energy. The solar energy that comes in only a small percentage of it is you know involved in that those percentages may vary based on what all is being considered, but its relatively a very small percentage which participates in this weather phenomenon that we see.

So, today in the way the world is progressing, the wind technology is actually being actively pursued by a number of countries, it is still not uniformly being pursued across the world. We will see, we will look at that information today. In our class, we are basically going to do an overview in this class of this wind energy area and then subsequent classes of course, get into considerable detail of specific aspects associated with it. So, today as I said internationally there is a lot of interest in it, there are specific companies that have you know grown up in this area and lot of effort has been made to capture wind energy. So, many places certainly, many places in India, it is common sight these days to see windmills to see what are called as wind farms because they have several of these windmills or wind turbines arranged in some periodic manner, some known some pattern they arrange it there and capture the wind energy.

So, that is the context in which we will look at things. So in fact, even the photograph you see here is from one of the IIT campuses, at IIT Palakkad, their current temporary campus that they are in, has this structure that you see here. Although the photograph is you know as is out there I particularly like it because it shows you everything it shows you the nature that we are trying to protect, it shows you the wind turbine that is out here and of course, it shows you all the transmission lines which is a key aspect of this technology. You need all of those things to be there for us to really utilize this process. And as I said this is there all over the world. I mean you see it many places, now increasingly it is visible you drive on many highways, you go to various cities somewhere you will see dotted on the skyline you will see these wind turbines increasingly becoming present.

It is considered a very clean form of energy, because there is really nothing we are doing there, we just have a fan that is you know we are not burning anything there we just leave this object out there which is the wind turbine and the wind does everything else the wind moves it rotates the turbine, you will generate electricity and use. There are still it is not that it is, it has got no issues it is definitely got some issues, but in the grand scheme of the issues that are being faced by you know the energy sector I would say relatively these are mild issues. So, there is no significant you know chemical pollution during the manufacturing process although they are looking at you know composite materials that are being used for those turbines there are the current blades that are being used are all composite type of blades.

So, there is some you know polymer processing that is being done for that. So, no doubt I mean so, we have to look at what how clean that process is so that is something that I mean in the grand scheme of things you may want to analyze that what not. But once it is out there it is just generating electricity based on wind, the few things that sometimes people grumble about with wind technology is in terms of its you know cleanliness or friendliness are actually really 2 or 3 things, a lot of times the local population somehow do not like the sight of these things you know it just, it is in some ways maybe they think it is an eyesore I mean they do not want to see they do not want to wake up every day and see this huge set of structures blocking their view.

So, it does block your view even if you are used to nature you are just seeing you know things around you then this is not something many people feel comfortable about even though actually it is not doing any harm, it is just sitting there kind of thing you just put these structures there and a continuously moving, so sometimes that causes unease to a lot of people they keep seeing this thing rotating and rotating and rotating they do not feel comfortable about it. I mean if you are driving through we just go past it, but if you are there if you are there and every time you look up you see this huge thing rotating in front of you it is not something that many of us are comfortable with. It also makes a slight amount of noise and it is a very kind of a periodic noise because it is not like a, unlike a fan in your house which is going at very high rpm, this is a much lower rpm.

So, you stand there and even keep hearing this noise, “woosh, woosh”, like that no noise to keep on coming and it is a kind of a periodic noise with enough gap in between those woosh noises that if you are there you will it will keep on disturbing you. So, you are

trying to do something your mind gets stuck in this noise which keeps on coming and it may affect people's ability to sleep if they are staying relatively close by, because it you keep on getting it they just nonstop it keeps coming. It is sort of like you know a dripping tap, if you have a tap dripping in your house sometimes that really bothers you, you cannot you know do anything because that noise of that drop repeatedly falling in the bucket or on the floor really affects your ability to sleep to concentrate and so on and that varies from person to person. Some people are you know they do not care that noise is there if they just are able to put it out in the background and forget about it and continue to do their things. Number of other people are sensitive to that, they find that very difficult. So, so there are issues like this.

There is also some criticism that people make saying that these rotating windmills can impact migratory birds. migratory birds can get hit and killed by these windmills and those incidents are true they do happen. Again you have to look at the broader picture there are various reasons both manmade and natural by which the birds get impacted in that scale of things again this is not considered as a large enough impact, although ideally we want to keep that impact to zero. So, that issue is also there. So, these are the kinds of you know issues that we are looking at as you know, in the you know broad spectrum of things that you have to look at when you step back and look at the technology because once you get close to the technology, it all always looks good you say oh this is nice, this is nice, this is nice and that will always be the case.

But you have to step back to see this grand scheme of you know what are all the things that it is doing and what is the impact. There is, there are claims that it up affects you know radar signals and so on. So, many many other things are there, but those are all perhaps not as critical to us as a general user. But, there are also many positives and that is the reason why we want to really look at it.

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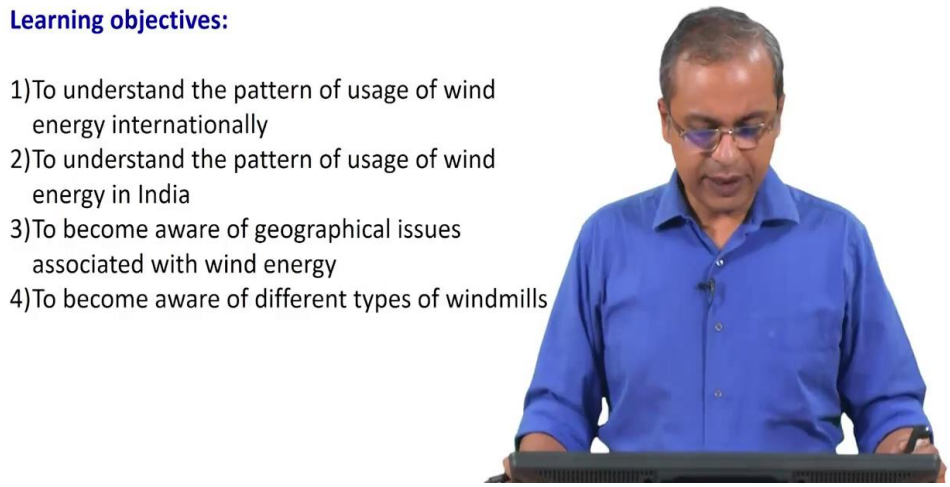

So, our learning objectives for this class are to the; to understand the pattern of usage of wind energy internationally and to also understand the pattern of usage of wind energy in India. So, where are we internationally with respect to usage of wind energy and even within India what is the you know pattern of usage. Also we would like to become associated or aware of you know geographical issues associated with wind energy water sort of concepts we have to keep in mind etcetera and also become aware of different types of windmills. So, perhaps you know I think especially the point number 4, I may discuss in greater detail, will some of these points we will discuss in greater detail some of them will discuss in less detail in this class, if necessary we will elaborate in another class. So, this is the general idea of what we are looking at.

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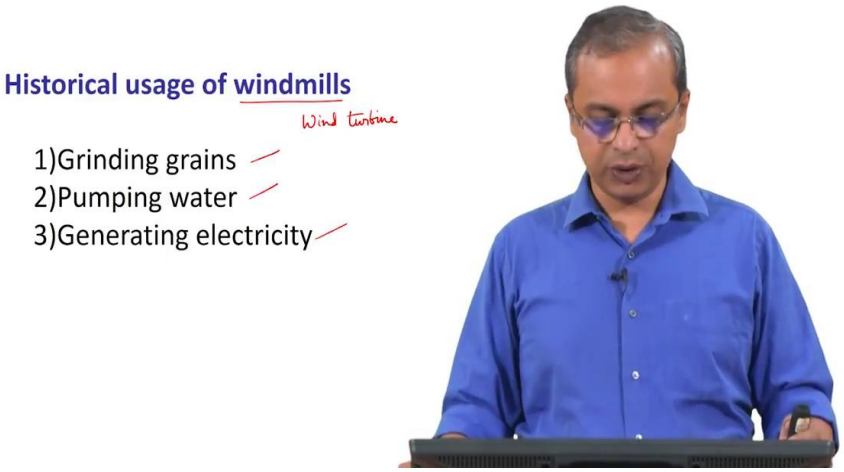

So if you start off by looking historically, first of all this term windmill, these guys we hear this word the usage of wind turbine. So, we tend to see in the news wind turbines, we do not necessarily hear the term windmill, but that is a matter of choice of what you are trying to convey. I think in the general public's perception they are essentially the same. I mean you see something out there which is rotating and that rotating movement is caused due to wind and because it is rotating something useful is being done. So, that is the general idea.

So, in the olden days historically if you see this has been used for a couple of different applications. In fact, the first was you know sort of for these two applications, for grinding grains and for pumping water. So, they were also considered as you know grinding mills kind of is the kind of idea that they had. The nice thing about this first two applications is that you know especially in these areas where the windmill was operating you just did not have to do much I mean once you set this up the wind would keep on doing its thing and you just have to you know feed the stock that needed to be ground and you will just keep grinding it and even water pumping. In fact, there are places where you know if you have some reservoir from which you want to pump water out using a windmill. Because this thing is just continuously operating you have to actually switch it off at times if you do not switch it off it will just empty the water I mean it will just pull out all the water and throw it out. So, you have to keep that in mind because it is just quietly running continuously.

In our homes when we put pumps to pump up water from you know sump underground to the tank above, because we are using electricity and you know we are you know conscious of those things we go and switch off the pump and there is an overhead tank we want to make sure that it does not overflow we go switch off the pump. If you just have a windmill to do that and people can install small windmills on top of their house which will do this pumping at least from the underground water some it will take it to the overhead tank without having to use any electricity. If you just leave it on it will just pump the water out, I mean all the water out and you may just overflow the tank up there if that tank on top of your houses has a lower capacity than the underground sump which is most likely the case then you will just empty the tank out you will empty the sump and there will be nothing left you will be just overflowing water out the top.

So, you have to be out because it is free you just let it run and then it will just do its thing. So, you have to be aware that it operates that way and you should be you know ready to switch it off, so to speak or stop it put a brake on it and halt it. So, this is what it had been used for historically. More recently of course, it has been used for generating electricity and that is why it is called the wind turbine because eventually we have some generator there and then you are generating electricity.

So, in our context largely we are looking at the electricity generation part of it, although emotionally you could use it for any of these other purposes also so that is always possible. So, that is the wind turbine and these are the historical ways in which it has been used and with that as our background we will keep moving forward.

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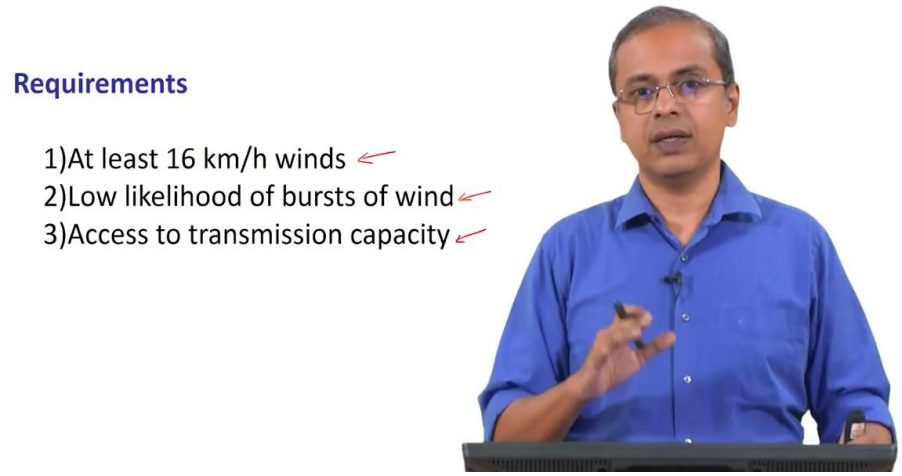

So, what are some general requirements? So, some general requirements for setting up this kind of a facility, I mean you may think you can set it up anywhere yes indeed you can set it up anywhere it will work with differing levels of effectiveness. So, it there may there may be locations where it is just come very very minimally effective. So, it really depends on you know if you want to get serious about it you have to really look at the cost benefit analysis right. So, you have put some cost to set up some infrastructure what is the benefit you are getting from it. So, from a purely economic sense that is the way you would look at it of course, from an environmental sense you have to look at the cost part of the equation as well as the benefit of the part of the equation in a much more elaborate manner. I think that is the key when people say it you are ignoring environmental considerations that is basically what they are saying.

When you write the cost benefit kind of analysis if you do not put cost to those things that are environmentally bad then basically you are not doing a proper analysis that is really what it means. So, in the cost-benefit analysis you have to put in the idea that you know this is the cost reporting of this wind turbine or windmill what is the benefit that I am getting out of it or what is the benefit that society is getting from it. So, this is the thing you have to keep in mind. Therefore, you need to set up this windmill in such a way that it works well, if it does not work very well then you are not getting enough benefit out of it then for the amount you are spent on it you are not really, the local people maybe yourself or the people around you who are depending on the windmill are

not getting the benefit of the wind. Generally speaking this is the kind of number that people quote that you would like to set it up in locations where there is at least 16 kilometers per hour winds on average. There is going to be significant variation through the day significant variation through seasons etcetera, on average we were we would like to have at least 16 kilometers per hour winds.

Also generally the preference is to put it up in locations where there is less likelihood of strong bursts of wind happening all of a sudden. So, there are many geographical locations for variety of reasons, you will have a situation where wind is relatively calm and then all of a sudden you will have a huge gust of wind for a significant period of time and then again it will stop and so these things are possible based on the geography of the location. So, at least you have to be aware of it, you have to know how to handle it, but those are not really the best places to sight the wind turbine. And finally, of course, you need access to transmission capacity because that is how you will get the power generated there to either the local houses nearby or two even if you are going to put it on the grid and then transmit it to some distance then you need access to that transmission capacity.

So, generally in a more you know systematic way of going about doing this they will look at all this analysis, they spend more than a year analyzing the wind patterns at a given location before deciding whether this is location is good enough to set up windmills because it is a fair amount of investment in the infrastructure and they would like to set it up in such a way that it really benefits everybody. So, significant amount of site you know analysis is it done before this windmill gets sighted allocated, all right.

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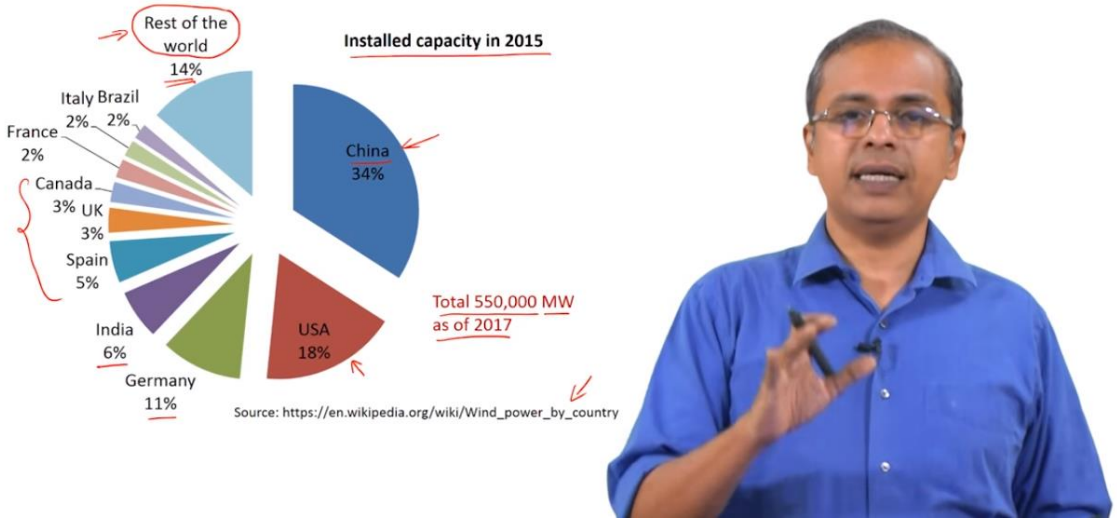

So, if you look at international usage of the wind energy and this is based on total installed capacity in 2015. So, these numbers keep changing in fact, especially with wind energy this number is changing pretty dramatically and I am going to show you some data with respect to that, but so, we look at this, we will we have to keep in mind that this is data to 2015, so with every year things might change. About one-third is in China. So, China uses one-third of as set up.

I mean if you look at you know the total capacity or that is being generated a total no power that is being generated one-third of the power is being generated by wind plants sitting in China. Of course, this is free I mean when the wind energy is free. So, nothing prevents anybody else from also setting up wind plants, but China has made a major push in that direction they have significantly invested in setting up wind plants. So, some of the largest wind plants are all sitting in China, I mean they have you know systematically done this and. So, they have several such wind plants that have been put in place.

The next is the United States, then you get Germany and we are here we are fourth we are not too bad actually we have our own approach to doing things we do not force fit solutions. So, we have you know a certain system we follow to come up with to decide whether we are going to do something and then go about doing it etcetera. We are right now the fourth largest such in terms of wind power capacity and wind power generation.

In fact, I would also add that we are amongst the generally if you look at the growth of wind energy, we are one of those countries where the growth is very significant. So, that is a very positive thing. The government is you know actively trying to get more wind energy you know farms setup and harvest the wind energy. So, this is being actively done in India and so our growth rate is actually relatively good in this sector. So, that is something that I know we can feel good about because that is the right direction we feel that that is one right direction to move in terms of the energy usage. And then you have Spain, you have United Kingdom then Canada. So, you can see that you know these are also significant countries, but they are all also I mean in a sense a little bit low on the in capturing of wind energy and then you see this few more countries here. So, we are already 4th, 5th, 6th, 7th, 8th. So, about 10 countries are listed here and then the rest of the world.

So, you can see it is a very disparate distribution, possibly a lot of places in the world could benefit from wind energy and you know once you set up this windmill you can get a lot of energy because at the end of the day you anyway have to set up some plant to generate electricity right. So, you instead of generated putting a coal plant there you can put a windmill there if you can compare the economics of it. Of course, people will put some you know amount associated with it and so you have to really do an economic analysis to figure out what works there, but that economy should you know ideally also take into account the environmental considerations. So, if you look at it the rest of the world is only at 14 percent.

So, we are doing almost half as much as the rest of the world I mean in that sense. So, to speak and China is doing more than the rest of the world in terms of at least what we are describing here as the rest of the world. Of course, these are all also the other countries are also part of rest of the world, but what is being clubbed here in the 14 percent is significantly small percentage of the capacity so to speak.

And the total that is being generated is about half a million megawatts right. So, half a million megawatts is being generated as of 2017. So, that is what is being generated by all the countries around the world and one-third of that is being generated in China. So, this is the current status. Of course, this is the source of the data which I have re-plotted here, but the data is available in that source you can go and take a look.

So, significant, the point you see here is that the significant variation across country. So, it has got a lot to do with the policy in that country. So, nothing because wind is just there I mean it is not that unlike coal or oil or something which you have to import from somebody this you do not have to import, it is right there in your country. So, it is only a question of the policy in the country whether you want to go in that direction whether you see long term that this is the right direction to go in and therefore, you encourage companies to you know set up these wind plants which are, who are willing to do so, and then find the locations assist them in setting it up etcetera. So, it is more a policy oriented issue rather than anything else unlike you know fossil fuels.

Fossil fuels we know geographically they are in some locations you have to buy only from those people. So, they it comes with some other baggage, here that baggage is not there it is really truly you know just like solar energy sun light. In fact, solar energy also you can say it is not uniform across the world because you will have places where you are having less sunlight you are having more sunlight all those things are there, but generally wind is there all over the place I mean it is just a matter of locating the right place. So, it is much more equitable across all the countries and so, you can utilize it. So, this spirit that you see internationally is significantly tied to the policies in these countries. So, that is what I would highlight.

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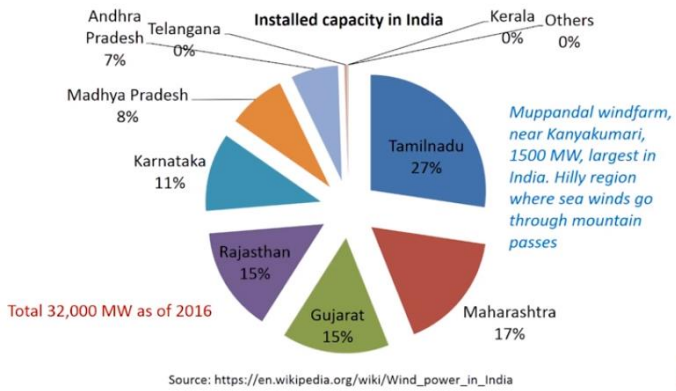

Even within India you can see that different states have made significantly different participation in this wind form process. Interestingly the number one state leading this effort is Tamil Nadu. So, they have done a great job in setting up this wind farms in the state it is the number one state in the setting up of these wind plants if you see. It is significantly more than even the number two Maharashtra is at 17 percent, Gujarat is 15. So, these are the four major states Tamil Nadu, Maharashtra, Gujarat and Rajasthan.

So, these are the four major states that have significantly put in efforts in the area of wind energy. Then you of course, you have Karnataka, Madhya Pradesh and Andhra Pradesh at the other others are relatively small. So, in this, in the scale of this diagram it is showing up at 0 percent, but that is it basically means it is significantly less than 1 percent that is really what we are looking at. So, you can see here 1 2 3 4 5 6 and 7. So, 7 states more or less are doing the much of the wind energy sector as an you know a sector that is generating power for any use it is really distributed across these 7 states even here you can there is this place called Muppandal, Muppandal windfarm. So, if you go to the southernmost part of India which is of course, the Kanyakumari, close to Kanyakumari there is a small village called Muppandal.

And there is the largest such wind farm that has been set up which is a 1500 megawatt capacity wind form. It is a very interesting place because it is a very small village actually and apparently it was quite an impoverished village, but this farm has really helped the local people, this wind farm because it is generating electricity and supplying to the grid. It happens to be a hilly region there and there are strong gusts of wind which go through the mountain passes. So, you have strong winds going through mountain passes and that therefore, it becomes an ideal place to set up these wind turbines.

In fact, those of you who have traveled to Thirupathi also will see you these wind turbines dotted on those hills. So, many of those places you know as you gain in altitude you get the strong winds blowing in different directions. It is also very historic place this Muppandal, I mean it is associated with an ancient Tamil poet Avvaiyar, and she is supposed to have been at this place and she is actually supposed to have worked very nicely with 3 different what shall I say kingdoms that were there at that point in time, three different kings and dynasties that were there at that point the Cholas, the Charis and Pandyas. And I mean just oh just out of historical you know relevance she had managed to get all 3 of them to attend some event and they had set up pandals for from on behalf

of each of them. And since there were 3 such kingdoms, there were 3 such pandals and hence the name Muppandal, the mu stands for three and the pandals, are the pandals that they put in place.

So, that is just you know interesting historical take on the place, but really it is now famous for this you know a wind farm that is set up there, you see this in them you know I guess sort of in the middle of nowhere you have this wind farm and that has contributed significantly to the overall generation. You can see here 32,000 megawatts as of 2016 that is what India is generating as of now, 32,000 megawatts and out of this you know almost thirty percent is there in Tamilnadu. So, Tamilnadu has a significant contribution in this activity. And the government is actually actively trying to push this to about say 60,000, about 60,000 megawatts by 2022. So, at least there is some intention to push it to almost double this in the next 6 years or something.

So, these are all I would say you know heading in the right direction from the perspective of you know making ourselves environmentally friendly and therefore, it is very nice and welcome sign to see.

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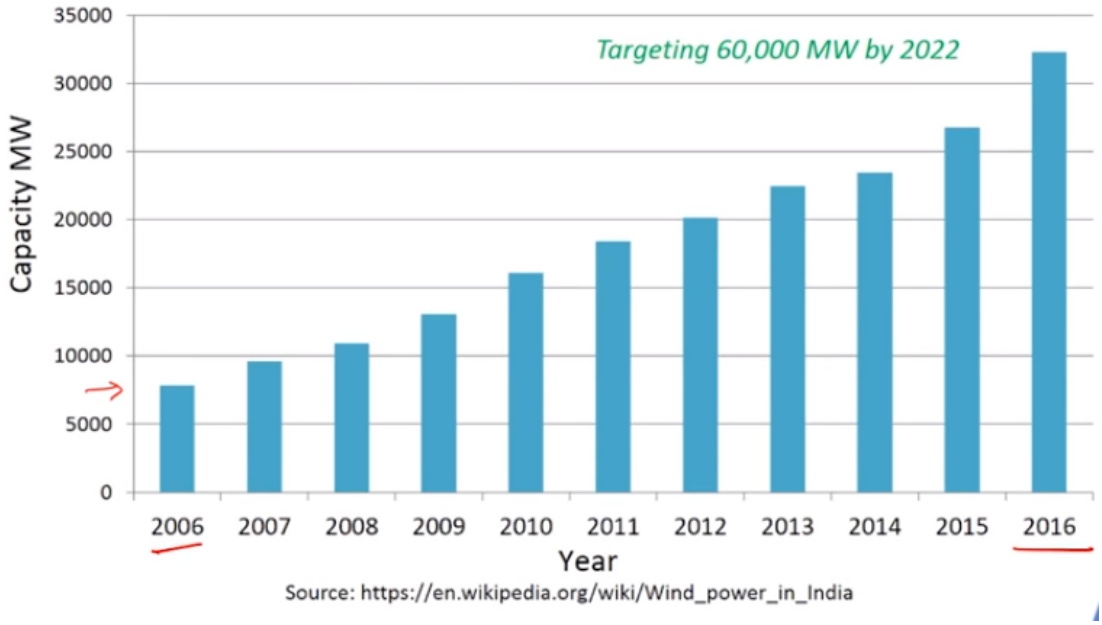

So, if you see here, this is a trend which I thought I should show you because this is also true internationally. You can see here from 2006 to 2016. So, that is about 10 year period

during which this was this must have been about 7500 megawatts from there we have gone to about 32,000 megawatts. So, that is what that is about more than 4 times increase. So, four and a half times, so 450 percent increase in capacity in 10 years. So, that is very significant. Almost if you look at all the technologies that are out there which are being you know deployed into the public domain for people to use from the perspective of inner energy usage, this is a sector which has really grown very significantly.

Roughly even, in India if you see here roughly you will see about you know something like 15 percent, 20 percent, 30 percent growth from year to year. So, for example, you see here this is about this is also about 27,000 something and this is 32,000. So, you have grown by about 5000 in the space of one year 5000 megawatts in the space of 1 year with a value of about you know, so about just about just under 20 percent, just under 20 percent is the kind of growth that we are seeing here and this is true internationally also. Even internationally if you look at the various countries who are trying to push this technology forward many of them are pushing in this in this kind of percentage 15-20 percent growth. So, for any industrial sector to be moving in this manner where it is growing by 15-20 percent every year it is a very promising sign I mean for that industry it is a very promising sign. So, all the capacity is built correspondingly and that is a great sign to have. So, that is what we are looking at.

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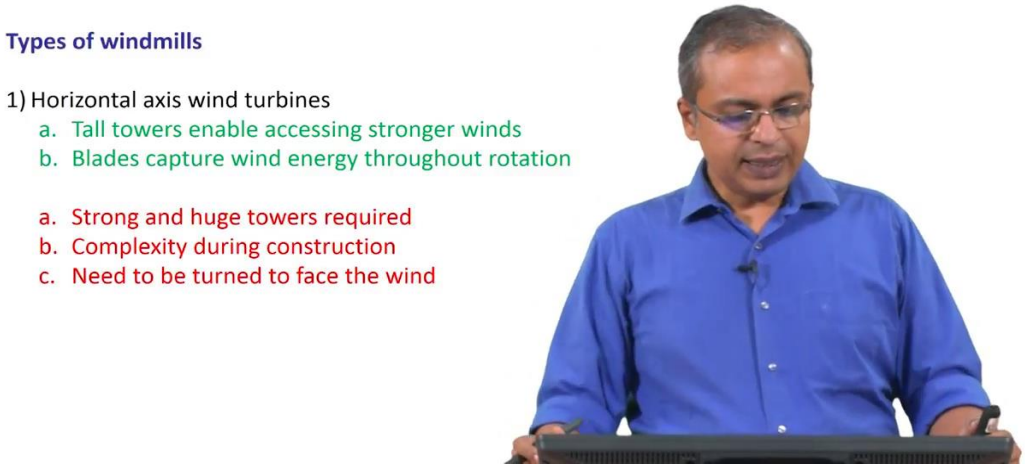

In terms of types of windmills, we will as I said you know maybe examine this even more as we go forward, but here itself we would I would like to share with you some ideas related to these types of windmills. So, broadly there are two types, the first one is listed here, the horizontal axis wind turbine and as you make as you can guess maybe the other one is the vertical axis wind turbine. So, very briefly it would look something like this, we would have some kind of a tower, some tall tower and then on that we would have some structure, from this you would have a shaft that comes out and that is your horizontal axis, horizontal axis. So, something that is out here and then from this you have the blades. So, this is how this would be set up.

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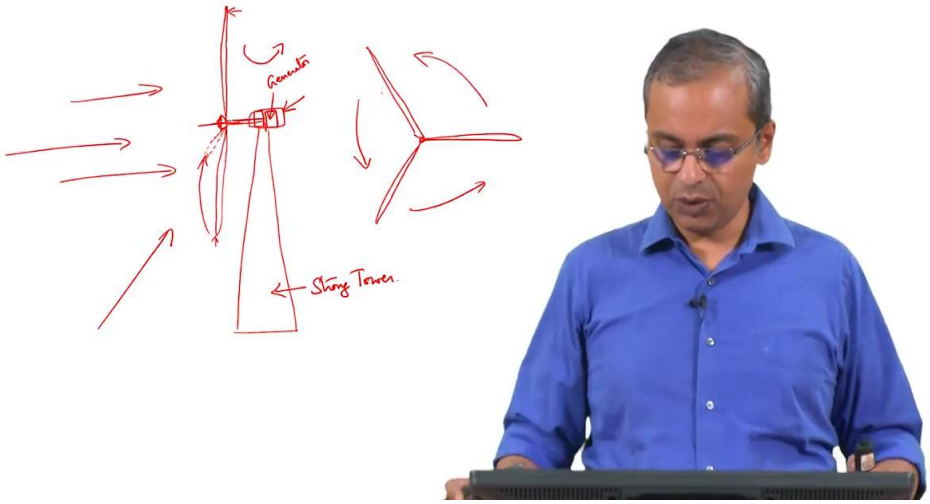

So, you would have wind coming in this way. So, the wind is coming horizontally and then this turbine keeps rotating and then generates electricity. So, this is the general layout of a horizontal axis. So, this axis is horizontal and that is what they are referring to as the horizontal axis wind turbine. Maybe the name does not seem significant to you, but when you look at the advantages and disadvantages you will understand what we are talking about.

So, the first advantage is that what I marked in green are the advantages the tall towers enable accessing stronger winds. So, one of the issues you see here is that you know you want to get good wind, we are going to do some calculations later about what is the why is this. So, important for us we would like to access stronger and faster winds and taller

towers usually you know when you have a very on the ground level you see more obstruction from various you know even just the terrain, terrain will obstruct the flow of the wind and, you do not actually get the strongest of winds. So, if you go up in buildings even any tall building you go you can feel strong winds and if you are in tall buildings. In fact, you have to be very careful in tall buildings because doors slam very hard because of the wind that is there.

Same building you go to the first floor you will not have this problem. So, therefore, the stronger winds are there if you go up in height and therefore, and in this case that is a plus because you are trying to capture that energy. And the blades capture the wind energy throughout the rotation. So, this is a very important point. So, if you see here this blade that you see here this bottom blade that you see here, it does not matter where this water blade is, if the bottom blade could be here or it could be it could have reach the top point out here or it could be somewhere in the end root it is you know journey. So, it is let us say it is going this way it is rotating that way.

So, even as it is anywhere in the middle if it were in this location even at that point the wind is actually going to hit that blade and generate and keep pushing the blade. So, it is going to keep you know various ways in which it moves the blade, but the blade will keep moving because the wind is continuously interacting with it at any point in that circular motion. So, it does not matter whether the blade is in this orientation or it is in that orientation or it is in this orientation. As the blade rotates, it does not really matter where the blade is the wind is coming from the front and it will always keep moving all the 3 blades. So, that is the point that we need to keep in mind.

But the disadvantages are that you need strong and huge towers when you set this up and the reason being. In fact, on this tower itself you have a gearbox here and you have the generator here. So, this is where the generator is. So, a fairly heavy structures now sits on top of the tower and therefore, you need to have a very good tower strong tower is required. So, this becomes a necessity, you cannot just do without a strong tower and that becomes a necessity. And this adds to the complexity during construction because you are need to have the strong tower and that you know hole you need the generator everything has to be lifted to the top of the tower and place there correctly. So, it is a complicated in the construction and it needs to be turned to face the window. So, that adds complexity again to the structure because it means if the wind direction were to

suddenly change you know, I mean I am not showing you in coming this way, but supposing the wind were to come this way then you would have to rotate this structure. So, that the blades now face the wind. So, this is rotating this unit on top. this unit this entire unit along with the blades so that the blades keep facing the wind and that is when you get the best benefit out of the structure.

It is an activity that you have to you know account for. You have to have a system and you know the correct kind of bearings may be some active way in which you will get it to rotate, some feedback loop which tells you which direction the wind is and keep it oriented towards seven. So, it is an activity that you have to acknowledge and do so. So, therefore, that adds to the complexity of this structure. But in general this is the more popular way in which the windmills or wind turbines of today operate. So, this is the thing, but it has pluses and minuses that is what I wanted to share with you.

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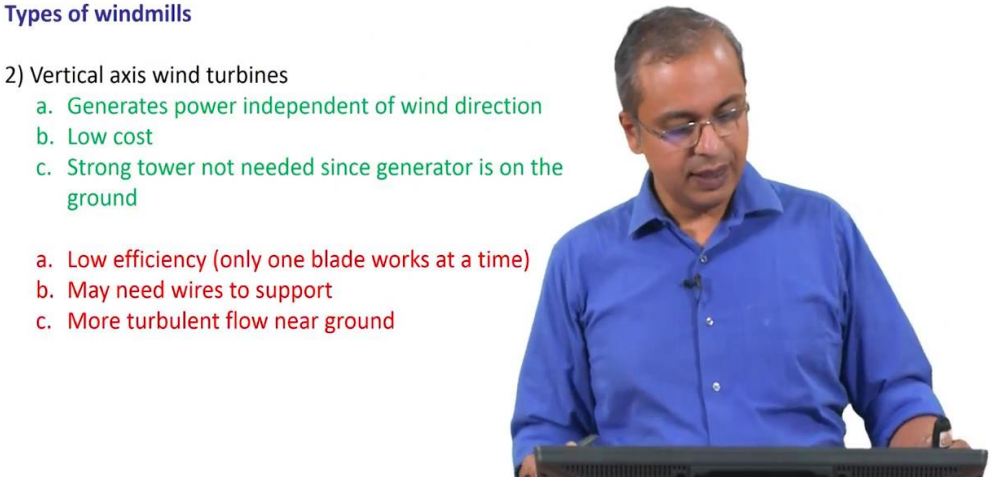

The other option you have is the what is referred to as a vertical axis wind turbine. Again as the name suggests the axis of the turbine is vertical. There are very many interesting designs for this turbine. So, I am just going to draw and very simple a type of structure just to explain what we are trying to deal with here.

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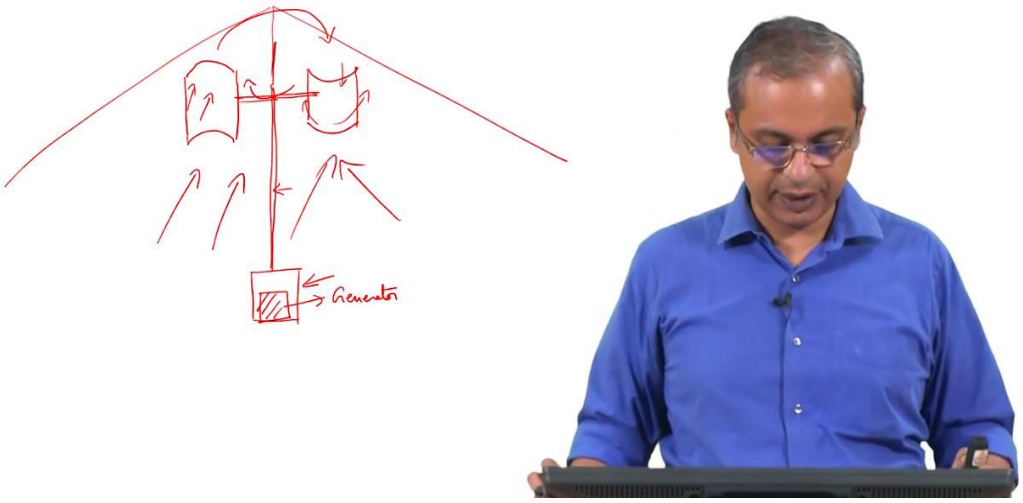

So, this is the axis of the windmill and it is something this or the base and here you have the you know something that goes out on this side and this side and in that you have the let us say I will just draw something like this and in this case. So, something like this is your wind turbine. So, here on the base you will have the generator. So, this is the kind.

Now, this is the axis, this is the axis and that is vertical. So, axis is vertical and that is what they are referring to. So, now, the advantages and disadvantages are like this. The one advantage is that it generates power independent of wind direction, it does not matter which direction the wind is coming because the axis is vertical and the wind is essentially horizontal. I mean unless the wind suddenly starts going vertical which is not what we typically see in a day from the perspective of the wind turbine typically the wind is horizontal. So, once it is horizontal it does not matter which side the wind is coming from because the axis of the generator axis of the wind turbine is vertical and since it is vertical the wind is always perpendicular to the axis it does not matter from which direction it is coming. So, and that you can see that here because as this thing rotates it is say it does not matter whether the wind comes this way or it comes this way it does not really matter the wind turbine will keep rotating and you do not have to do anything to re-orient the wind turbine it will rotate, it will just keep rotating. So, that is the one big advantage of it.

It is low cost, partly because of this thing that you do not need this strong tower since the generator is from the ground. So, the generator is placed in the ground here and therefore, you do not need, this tower does not have to be any fancy tower some basic requirements is all that it needs to meet and then it is in a position to operate.

Disadvantages are that first of all it is a little low efficiency type of a windmill or wind turbine, mainly because only one blade works at a time. So, why is this the case? If you look at the image you can see. So, let us say the wind is blowing this way. So, it actually pushes this blade here and then it actually runs off of this blade on the sides. So, it does not push this blade as much it pushes this blade more. So, as a result it rotates this way.

So, effectively at this point with these two blades available to you only the blade on your left is the one that is actually pushing and moving the axis, the blade on your right is actually not participating in the process if anything is providing a slight resistance to the process. So, it is actually not effectively participating in the process. And therefore, in terms of capturing energy this is less efficient, you are actually wasting some energy whereas, in when you did the vertical windmill where the I mean horizontal axis windmill where the turbines were I mean where the axis was horizontal, the all the blades were always you know reacting to the wind it did not matter which position the blade was right. Whereas, here as long as this blade is here, it does not respond to the wind when it rotates around and comes to this location it will be the one that is getting pushed the other one will stay benign. So, therefore, only one blade operates at a time and therefore, it is less efficient relative to the horizontal axis wind turbine.

And it may need wires for support and this again depends on the structure because it is a very thin structure, so usually they will have some system by which you know they will take this turbine I mean this shaft and then they will tie it to the ground somewhere they will tie it like that, in some three places to keep it stable. So, that it does not topple. So, that is the activity that they would have to do. And it is usually since it is at lower, lower location, it generally there is more turbulent flow it is not a very you know smooth flow of air because there is a lot of you know resistance from the ground the air bounces off the ground. So, instead of air going flat it may suddenly go up and suddenly come down and you will have higher movement in all different directions closer to the ground and because of various obstructions that are present. And so, the flow is much more turbulent

it is not very smooth laminar kind of flow so to speak. So, these are some disadvantages when you look at vertical axis wind turbines.

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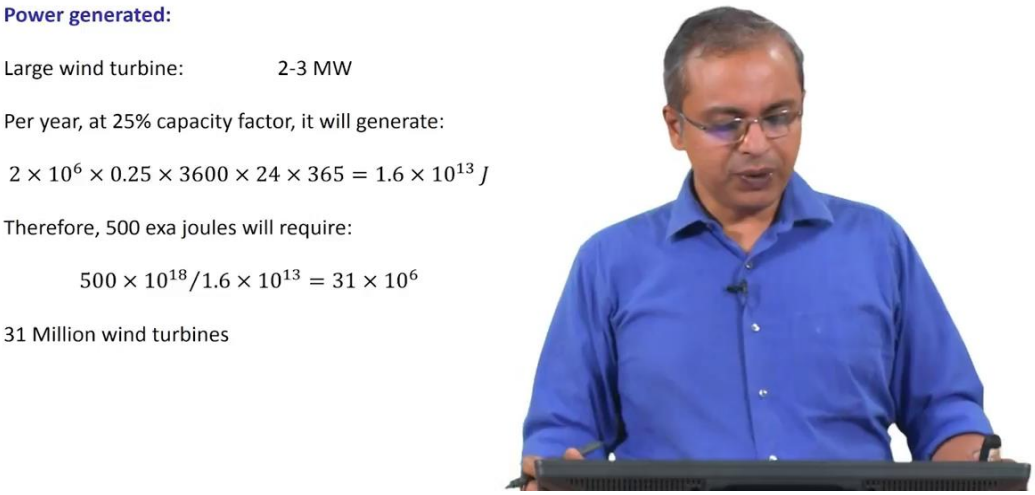

Just to give you an idea of what are we talking about let us look at the power generated. If you look at the commercially sold wind turbines some of the large ones that are being sold these days and are being installed internationally these days are having capacity of the order of 2 to 3 megawatts, as of today that is the capacity that they are having and those are the larger ones. You may find once less than this 1 megawatt and even 500 kilowatts may be there and are probably, there these are the slightly larger ones and so, if there is a large scale investment maybe they are using these larger ones. So, let us look at what it generates per year.

So, we have something called 25 percent capacity factor. So, what this means is that even though we are rating it at say 2 megawatts, 2 megawatts because the wind varies through the year through the day keeps on varying right. So, because of that it is not actually going to give you 2 megawatts consistently there are times it is going to give a lot less than 2 megawatts sometimes it is going to get you closer to 2 megawatts so on.

So, this factor simply says on average it is giving you 25 percent is what it says, that is what it means 25 percent capacity factor means on average across a year after if you average it across significant period of time you will be getting one-fourth the capacity

that it is rated for. So, in this case you will get 0.25 into 2, let us just assume we are working with the 2 megawatt wind turbines. So, you will get about 0.5 megawatts is what you are going to get.

So, if you take this thing and let us just see calculate what are we getting through the year. So, we will have this 2 megawatts, 2 into 10 power 6 into 0.25 and then let us look at what we get through the year. So, we have 3600 seconds in an hour 24 hours in a day 365 days in a year right, so you multiply all this you will get 1.6 into 10 power 13 Joules, so 1.6 into 10 power 13 Joules.

We always said that you know humanity is using 500 exajoules per year so to speak. So, 500 exajoules is there, so that is 500 into 10 power 18 joules and if each wind turbine is giving us 1.6 into 10 power 13 Joules. How many turbines will you require? Well, it turns out you need 31 million turbines, assuming nothing else changes and this is all that we are going to do that today's usage, today's windmill all that we take into account, know. But actually in reality these numbers will change you may get better wind turbines you may get you know higher capacity wind turbines, our power usage may go up, we may have more efficient ways of using power, power usage may come down. So, we do not really know all that. So, just using today's values this is the kind of number that we come up with.

So, if you actually put up 31 million turbines around the world, you can take care of the entire requirement of humanity, entire energy requirement of humanity it is just I mean I just wanted to do this calculation. So, you get some idea of the number we are talking of and so that is the number we have right 31 million turbines. So, how much area will this require? So that is another thing that we have to look at.

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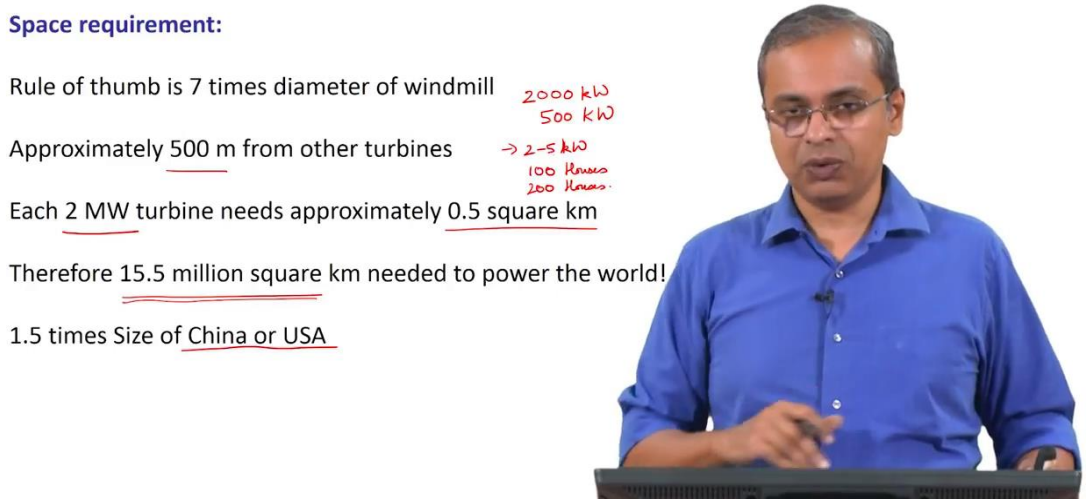

Generally what they say is that you know if you cannot keep wind turbines very close to each other because when one wind turbine is rotating it impacts the flow of air just past the wind turbine and therefore, if you keep the next wind turbine just next to it the second wind turbine works very ineffectively because it is getting a very bad flow of air you know air flow is just not back to its normal sense. So, normally they say a rule of thumb is that at least 7 times the diameter of that windmill. So, whatever the diameter of the wind means 7 times the diameter you should put between 2 windmills and only then you are reasonably sure that each windmill is roughly acting independently right.

So, that it turns out that roughly you are looking at about 500 meters between turbines that is the kind of distance that you would like to keep between turbines so that they do not impact each other negatively. So, some calculations I have shown you. So, if you actually go down to the ground and you see what people have set up. So, various wind farms that have been set up at various places where they have sited it and you know map the site and then located it and distributed it across the site etcetera. It turns out that it seems like that you need about half a square kilometer for each wind turbine you set up a wind turbine. So, half a square kilo meter around it you should not sight another one. So, you should keep it past that point. So, half a square kilometer you should require for each wind turbine. So, we are really looking at you know if you look at a half a square kilometer you will need about 15.5 million square kilometer.

So, since you need 31 million you know turbines to power the entire world, I mean it is just a hypothetical calculation because just to get an idea of what we are dealing with here because we need to know what is the scale of it right. I mean if you just if you think something is interesting something is very fancy, oh let us go ahead and do it that is not how you are going to power the world. To power the world you need to know what does the world need, the world needs 500 exajoules you have to check whether the technology you are coming up with has a capability of handling 500 exajoules. And if it is going to use I mean supply 500 exajoules what is the impact of it what are all the other things that are going to be required for supplying 500 exajoules. So, this complete picture you need to have.

And this kind of calculation you know gives you that scale of that complete picture and that is the reason why I am showing you this. So, we will need about 15.5 million square kilometers across which these windmills will be located and with that you can power the entire world. Just to give you an idea that is about one and a half times the size of China or United States. They are both around you know 9 million square kilometers something. So, so this is one and half times the size of China, with respect to India it may be like 4 or 5 times the size of India. So, that is the area across which you have to you know fully distribute the windmills to power the entire world.

On the one hand that may seem like a lot, but on the other hand if this is something that you can distribute across the entire world. So, this is just to give you an idea that this is what is required you can distribute this across the entire world and there is no pollution involved there is nothing involved, and it is also off the ground. So, presumably they have to think of windmill designs to see how you can integrate it with respect to with the rest of society and still capture the wind energies without compromise so that it does not mean that this 15.5 million square kilometers is lost. So, you should be able to you know put it on top of tall buildings or something. So, you have to design buildings where on top of the building you can set up a windmill so you get the height because the building is there you already have a tall building on top of it you can set up a windmill. Already there are buildings of that nature. There are buildings where on the top of the building they set up a windmill and it generates enough electricity or more than enough electricity to power the entire building right.

So, therefore, that is always an interesting thing to look at. So, for example, even if you if you see here no so, when I said 2 megawatt turbine. So, 2 megawatt turbine at 0.25 percent I mean sorry 25 percent capacity right. So, that is what we are getting that is what we said here, 25 percent capacity factor. So that is already we are looking at 2 megawatts giving us 500 kilowatts right, 500 kilowatts right. So, as opposed to 2000 kilowatts as opposed to 2000 kilo watts, 2 megawatts would be 2000 kilowatts and from that we are getting quarter of it, so 500 kilowatts we are getting.

So, a house as I said we will typically you need anywhere from 2 to 5 kilowatts right. So, we will take half half the value two and half, somewhere in the middle it will over to say we will say 2.5 kilowatts per house or some or even if you take 5 kilowatts if you take 5 kilowatts you can power 100 houses all right, 100 houses can be powered. If you take half of it you can power 200 houses. So, basically if you put a wind turbine on top of a tall building even you know you know say a 50 story building, 100 story building etcetera with the right capacity and that there you get very strong winds, so your you know utilization factor may be much higher than this your capacity factor may be much higher than 25 percent if you do that the entire building can be powered by just that one wind turbine on top of the building.

So, clearly there is a model there. you can you know construct various buildings on top of them you can have appropriately sized windmills. So, you are not loosing that area when I say 15.5 million square meters. So, square kilometers that area is not lost you are built a building there on top of the building you are placed it. At a location now where for example, these days they are placing all these towers for sending out the mobile signals mobile phone signals are being know sent off of towers which are on top of all sorts of buildings.

So, you can do a combination of all these things, you can have a wind you know I mean windmill, you can have a tower which is also doing all these communication signals, although they may have some interference we do not know about that, but all these models are possible. So, that you are generating power in a clean way and no transmission loss because you are more or less powering this building right there. So, you do not have to transmit somewhere and you know have all the transmission losses, transmission infrastructure is avoided so that also sales cost. So, many many factors are

there which are very interesting to look at and can be considered when you look at this kind of a picture right. So, this is something that is very interesting to look at.

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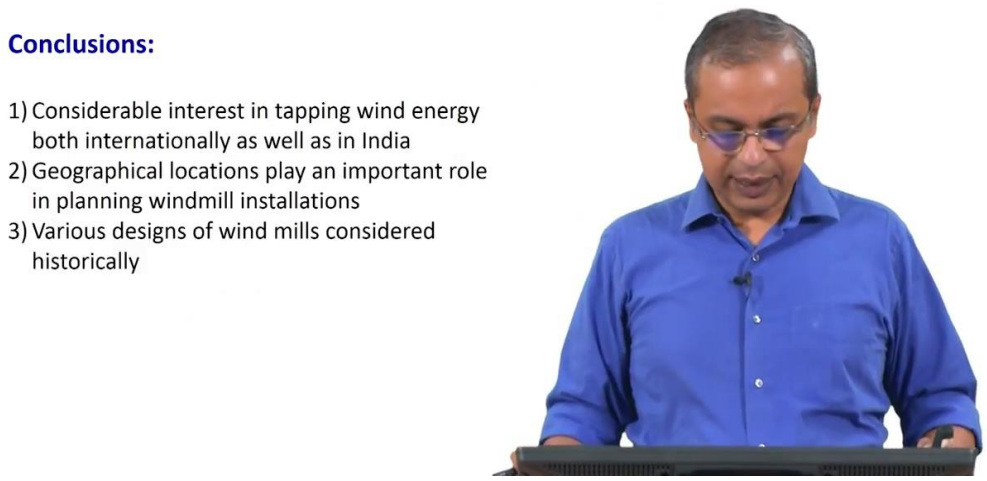

So, let us look at the conclusions here. First of all there is a considerable interest in tapping wind energy both internationally as well as in India and that is strongly seen by the fact that you know even in 10 years time we have grown four and a half times which is huge. I mean 450 percent growth is massive growth in any sector in 10 year time. I mean every year we seem to be growing about 15-20 percent relative to where we were last year. And this trend is being seen in many countries, any country that has got into this seems to be actively pushing it.

Geographical locations play an important role because as we saw you know this Muppandal area where they have set up this large wind farm is because geographically it is like that the wind flows there strongly and it is able to get you the kind of energy that we are interested in capturing a more effectively and therefore, that is a nice place to site it. So, therefore, you have to plan a little to site the windmills. So, that it really gets you the energy that you want.

And also I told you there are a lot of interesting models you can set it up on top of buildings, so it mixes up both the fact that you are living in a place and the fact that you are generating electricity right above that place and you make yourself self sufficient,

you make yourselves and environmentally free, clean you make yourself very efficient. I mean many times half the electricity bill that we are paying is for the transmission cost not for the generation cost. So, that transmission cost is gone. So, you are getting cheap electricity. So, you can power you are building and you can power a neighboring building. So, that is great, so many such things that can be looked at.

Various designs of windmills or wind turbines have been considered historically. We did not extensively looked at look at it, but we did look at the idea that at least two of major design differences here are that the axis could be either vertical or it could be horizontal. And I showed you that the horizontal axis actually has many advantages whereas, the vertical axis has some advantages, but it has some disadvantages as well and as a result you cannot you know it is not as effective. The horizontal axis windmills are able to capture the energy throughout their rotation process whereas the vertical axis ones are not able to do so, even though they are relatively cheap and economical to work with.

So, those are our major conclusions for this class. We have many other things to look at with when it comes to wind energy, we have to look at say energy considerations what are the kind of calculations involved when you look at you know, what is the energy that is available to capture what is the energy that we are capturing what is the room there for us to actually improve this process and so on. So, that is something that we need to consider. And also these designs as I said wide range of designs, wide range of designs have been considered many new designs are also being considered they may have their own pros and cons from any perspective. It could even be a psychological perspective of the people who have those windmills installed in their locations because as I said there is some level of resistance and reluctance to these technologies because they sort of impact the vision you know the view that you get of the place when you see these large set of forms of windmills that have been set up.

So, number of things to be looked at and we will look at them as we go forward. But for today I think this is your introduction to the wind energy, we will take it from our next class.

Thank you.

Introduction: In this lecture, the concept of wind energy capturing is discussed. The pattern of wind energy usage in the world and in India, different types of wind turbines, are explained.

Keywords: Wind energy, world scenario, Indian scenario, geographical aspects, types of wind turbines, horizontal axis wind turbines, vertical axis wind turbines.