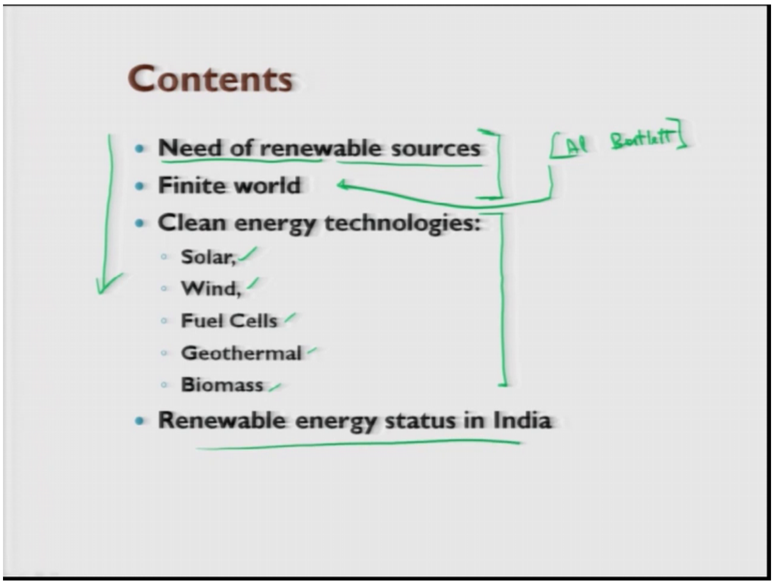
Sustainability Through Green Manufacturing System: An Applied Approach

Prof. Deepu Philip
Department of Industrial & Management Engineering
Indian Institute of Technology, Kanpur
Dr. Amandeep Singh Oberoi
National Institute of Technology, Jalandhar

Lecture - 22
Renewable Sources of Energy

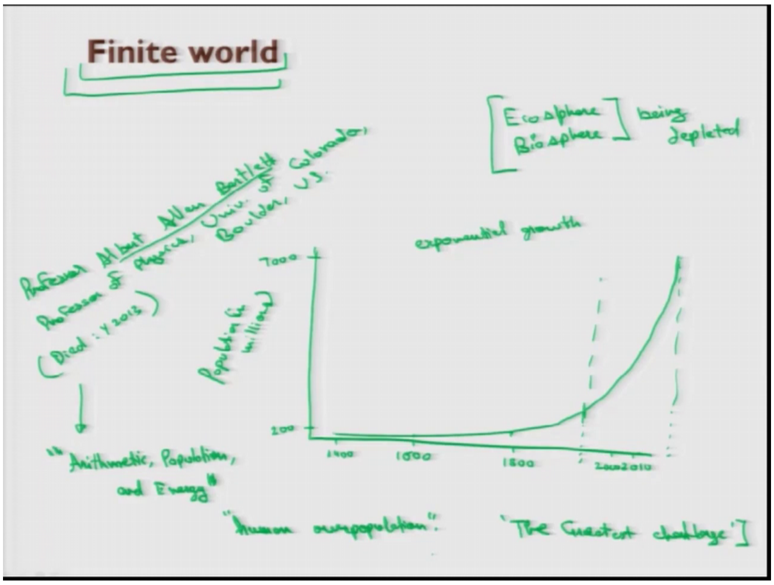
Good morning, welcome back to the course sustainability through green manufacturing systems and applied approach wherein we are trying to study the green manufacturing systems and certain sustainability aspects. So, in this lecture I would like to cover renewable sources of energy. So, what are renewable sources? Renewable sources are the sources that do not deplete while using.

(Refer Slide Time: 00:50)



So, this lecture would have a flow like this, first of all we will see what is need of renewable source see this I would like to discuss in detail, I would use a video by a professor Al Bartlett to explain that we are living in finite world then we will discuss various green technologies solar wind fuel cell geothermal and biomass then renewable energy status in India would be seen.

(Refer Slide Time: 01:31)



First of all we are living in a finite world the ecosphere we have or the biosphere we have that is being depleted. First of all let us see the population growth I started from 1400 to 2000 maybe 10 AD. So, it is growing like this. So, this is 1400 this is 1600, 1800 and 2000 and 2010. So, when I say total population in millions here today the total population in millions is about 7000 millions that is 7 billion people are there. So, this is population. So, you here in year 1400 it was about 200 millions only.

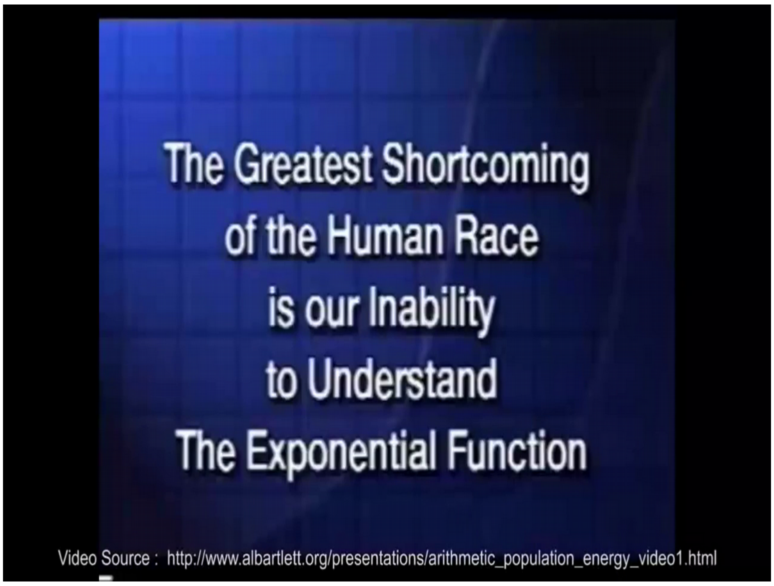
So, we can see that in last 200 years the population growth is rising. So, after that about this point the population growth is going like this. So, what is this curve? If you see it carefully this is exponential growth. So, what do you think what is this rate of population growth is it 50 percent population growth or is it 4 to 40 percent population growth per year no this rate of population growth is about 7 percent here. So, how is it showing the exponential growth here how is it going on this nobody can explain better than professor Al Bartlett he is his full name is professor Albert Allen Bartlett who did a great research in this he was actually professor of physics in university of Colorado at Boulder US university of Colorado Boulder US.

So, actually professor Al Bartlett passed away he died in year 2013 to professor Bartlett did a great research on human population growth he is one of the video named arithmetic population and energy is widely watch is widely seen on YouTube and this was a talk he gave on human over population. So, he was the one who highlighted that this is one of the greatest challenge of the mankind and how the resources which are being live depleted the rate of this depletion is growing like this in exponential way.

So, let us move to the video.

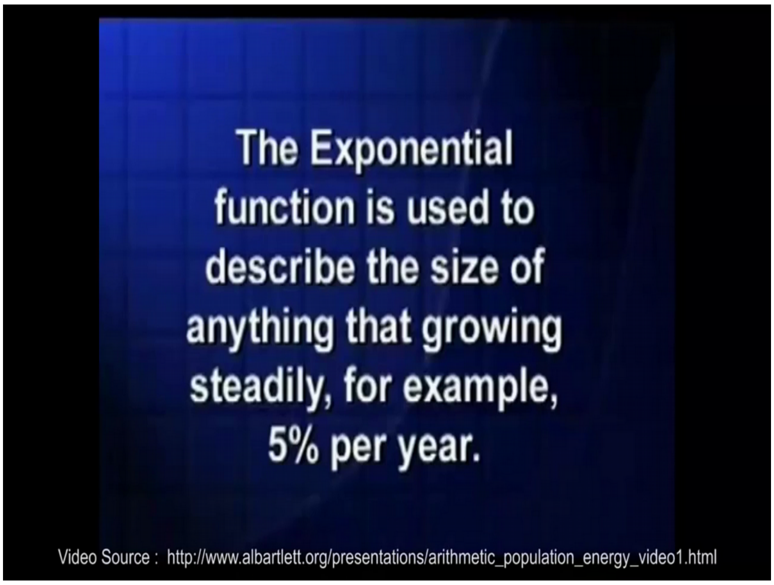
Well it is a real pleasure to be here and to have a chance just to meet with you and talk about some of the problems that we are facing. Now some of these problems are local some are national some are global, but they are all tied together they are tied together with arithmetic and the arithmetic is not very difficult.

(Refer Slide Time: 07:04)



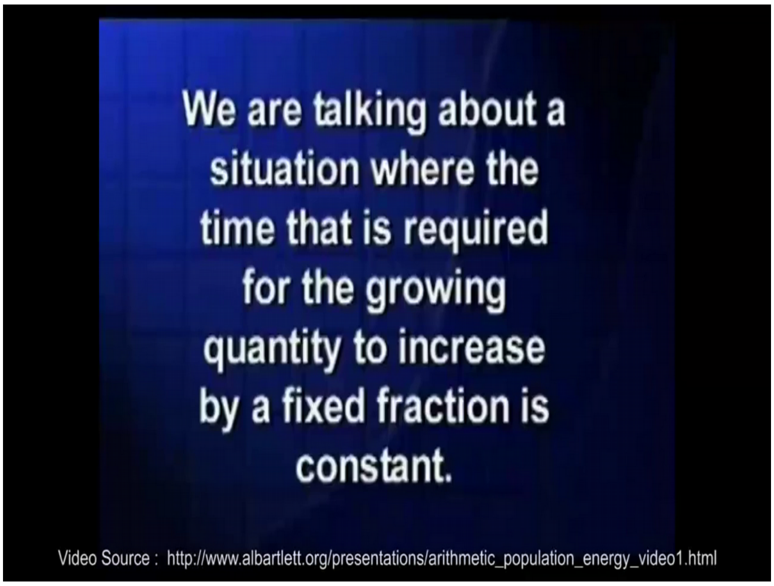
And what I hope to do is I hope to be able to convince you that the greatest shortcoming of the human race is our inability to understand the exponential function.

(Refer Slide Time: 07:14)



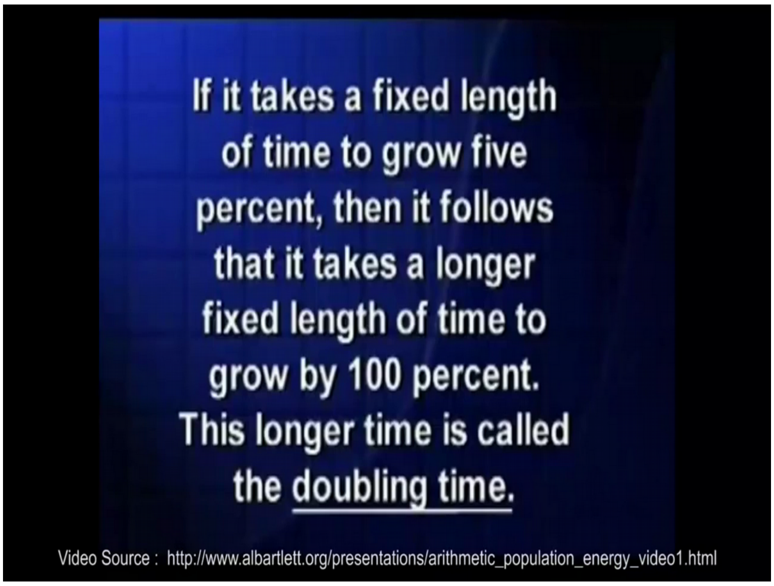
So, you say well what is the exponential function? This is a mathematical function that you would write down if you are going to describe the size of anything which growing steadily if you had something growing 5 percent per year, you would write the exponential function to show how large that growing quantity was year after year.

(Refer Slide Time: 07:32)



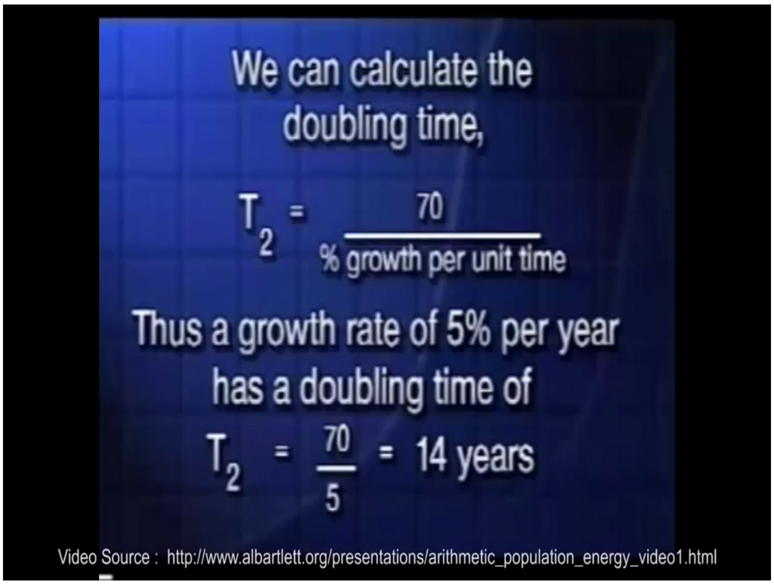
And. So, we are talking about a situation, where the time that is required for the growing quantity to increase by a fixed fraction as a constant 5 percent per year the 5 percent is a fixed fraction the per years of fixed length of time, now that is what we want to talk about its ordinary steady growth well.

(Refer Slide Time: 07:48)



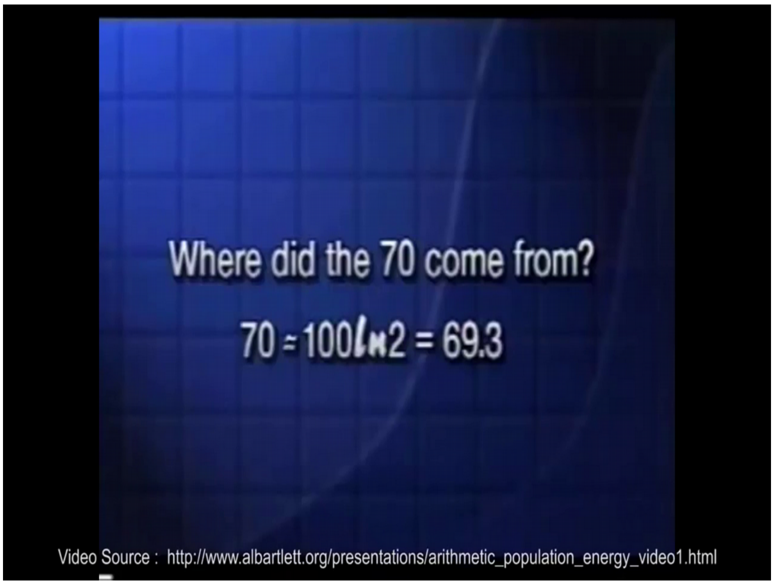
If it takes a fixed length of time to grow 5 percent, it follows it takes a longer fixed length of time to grow a 100 percent; now that longer times called a doubling time we need to know how you calculate the doubling time and its easy.

(Refer Slide Time: 08:01)



You just take the number seventy divided by the percent growth per unit time and that gives you the doubling time for example, of 5 percent per year you divide the 5 and 70 you find that growing quantity will double in size every 14 years well you might ask.

(Refer Slide Time: 08:18)



Where do the 70 come from; the answer is it is approximately 100 multiplied by the natural logarithm of 2.

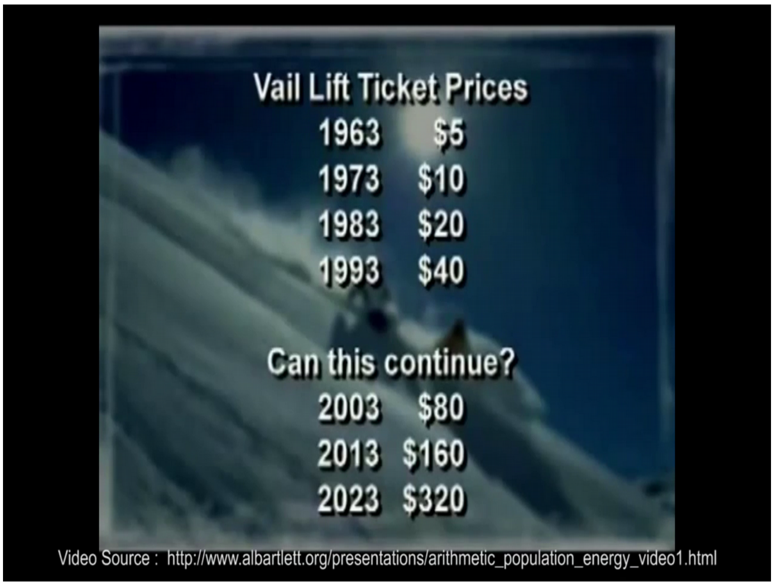
If you wanted the time to triple you would use the natural logarithm of three. So, it is all very logical, but you do not have to remember where it came from if you will just remember 70. Now I wish we could get every person to make this mental calculation every time, we see a percent growth rate of anything in a news story. For example, if you saw a story that said things have been growing 7 percent per year for several recent years you would not bat an eyelash, but when you see a headline that says crime has doubled in a decade you say my heavens what is happening, what is happening? 7 percent growth per year divide the 7 into 70 the doubling time is 10 years.

But notice if you are going to write a headline you never write crime growing 7 percent per year because most people would not know what it really means, now do you know what s7 percent really means.

(Refer Slide Time: 09:21)

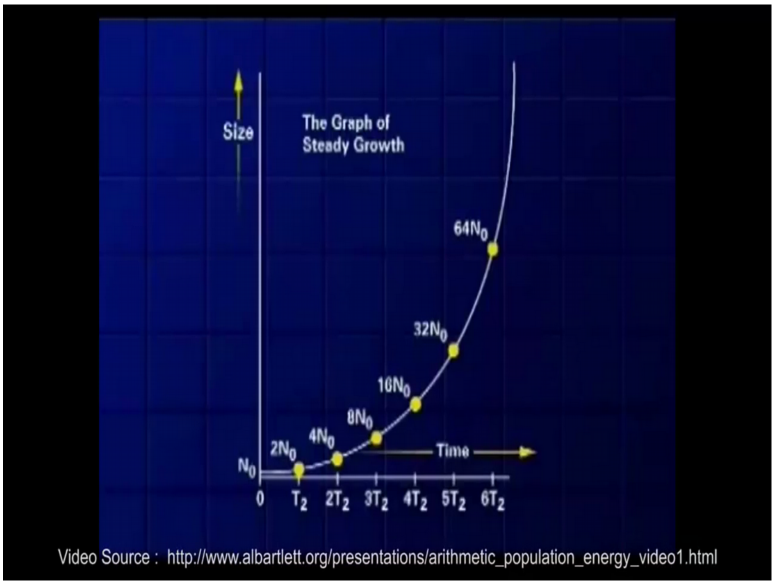
Let us take another example from Colorado the cost of an all day lift ticket to ski area has been growing about 7 percent per year ever since Vail first opened in 1963 and at that time you paid 5 dollars for an all day lift ticket.

(Refer Slide Time: 09:37)



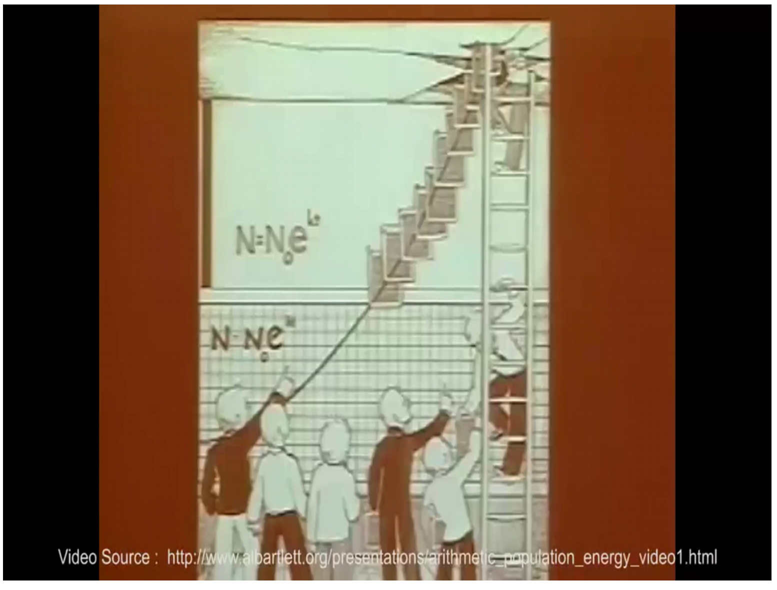
Now, what is the doubling time for 7 percent growth 10 years? So, what was the cost 10 years later in 1973, 10 years later in 1983, 10 years later in 1993 and what do we have to look forward to. Now this is what 7 percent means, most people do not have a clue well let us look at a generic graph or something that is growing steadily.

(Refer Slide Time: 10:02)



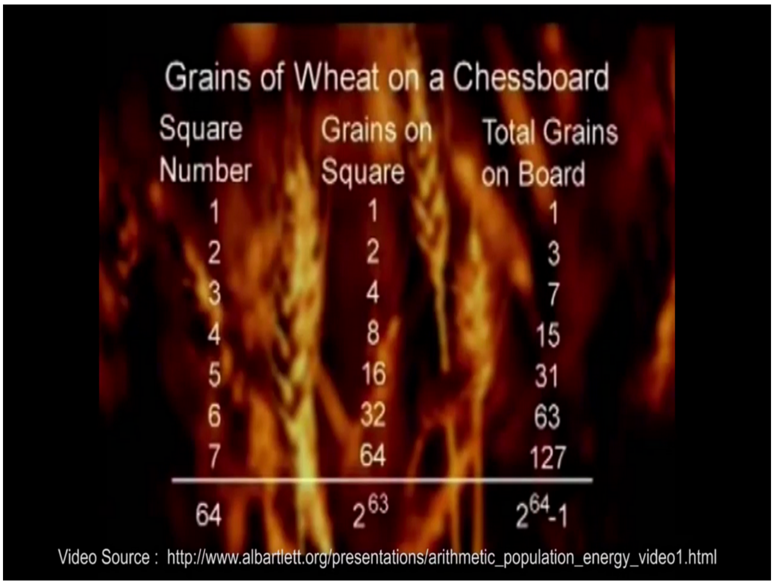
After one doubling time the growing quantities up to twice its initial size 2 doubling times it is up to four times its initial size, then it goes to 8, 16, 72 64, 128, 256, 5 12 in just 10 doubling times its a 1000 times larger than when it started and you can see if you tried to make a graph of that on ordinary graph paper the graph will go right through the ceiling.

(Refer Slide Time: 10:21)



Now, let me give you an example to show the enormous numbers you get with just a modest number of doublings, legend has it that the game of chess was invented by a mathematician to work for a king.

(Refer Slide Time: 10:41)

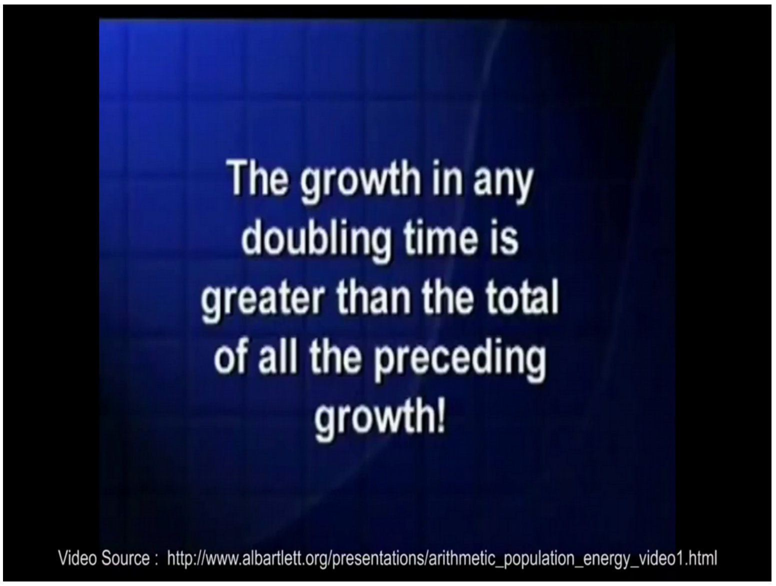


The king was very pleased he said I want to reward you and the mathematician said my needs are modest, please take my new chess board and on the first square place one grain of wheat on the next square double the 1, to make 2, on the next square double the 2 to make 4 just keep doubling till you double for every square that will be an adequate payment well we can guess the king thought this foolish man, I was ready to give him a real reward all I asked for is just a few grains of wheat well. Let us see what is involved in this we note there are 8 grains on the fourth square.

Now, I can get this number 8 by multiplying 3 twos together, its 2 times 2 times 2 its one 2 less than the number of the square. Now that follows in each case; so on the last square I would find the number of grains by multiplying 63 twos together. Now let us look at the way the totals build up when we have one grain on the first square of the total on the board is 1, we add 2 grains that makes a total 3 we put on 4 grains now the total is 7. 7 is a grain less than 8, it is a grain less than 3 twos multiplied together. 15 is a grain less than 4twos multiplied together well that continues in each case.

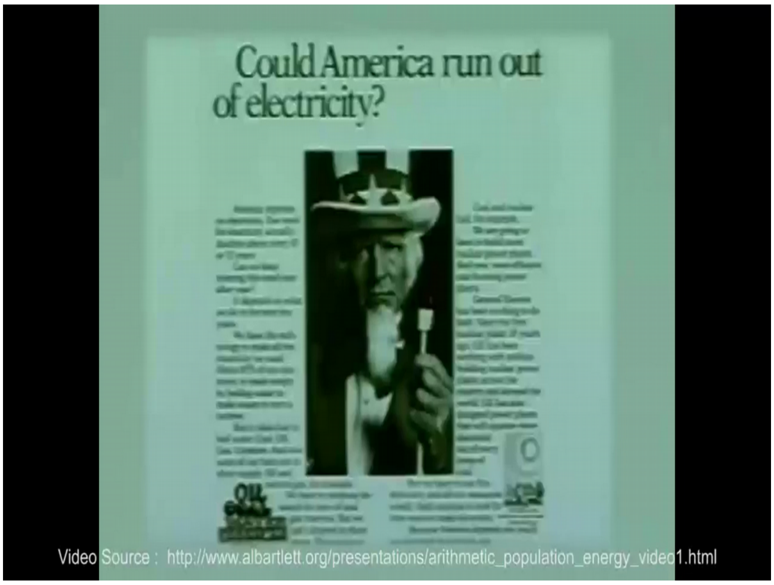
So, when we are done the total number of grains would be one grain less than the number I get multiplying 64 twos together my question is how much wheat is there you know would that be a nice pile here in the studio. Would it filled a building would it cover the county to adapt a 2 meters how much wheat are we talking about. The answer is roughly, 400 times the 1990 worldwide harvest of wheat. Now that could be more wheat than humans have harvested in the entire history of the earth you say how do you get such a big number.

(Refer Slide Time: 12:36)



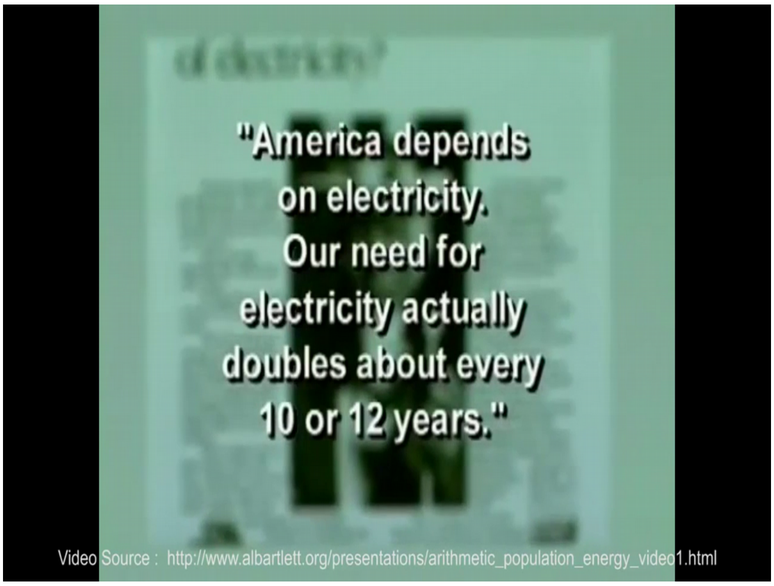
It was simple we just started with one grain, but we let the number grow steadily till it doubled a mere 63 times. There is something else that is very important the growth in any doubling time is greater than the total of all of the preceding growth for example, when we put 8 grains on the fourth square the 8 is larger than the total of 7 that already there when we put 3 grains on the 6 square the 32 is larger than the total of 31, that were already there every time the growing quantity doubles it takes more than all that you used and all of the preceding growth.

(Refer Slide Time: 13:06)



Now, let us translate that into the energy crisis, here is an ad from the year 1975 and then ask the question could America run out of electricity, America depends on electricity our need for electricity actually doubles every 10 or 12 years.

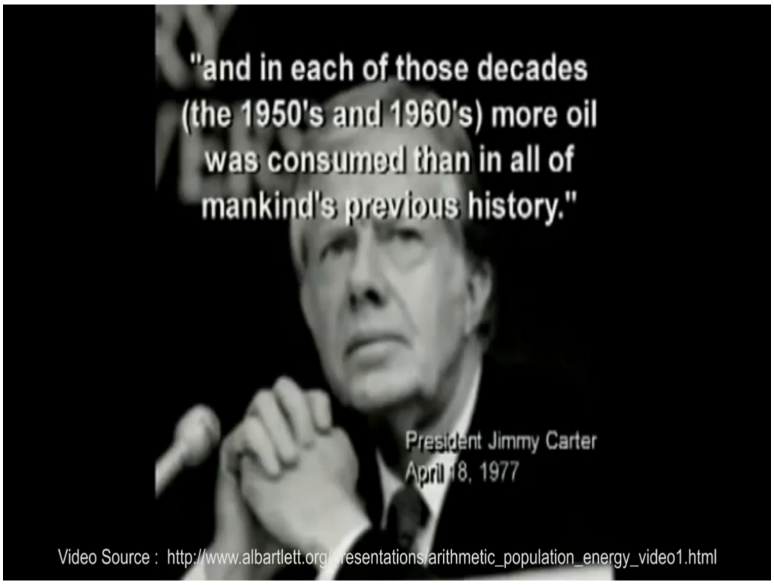
(Refer Slide Time: 13:15)



That is an accurate reflection of a very long history of steady growth of the electric industry in this country growth at a rate of around 7 percent through year which goes with doubling every 10 years. Now with all that history of growth expected the growth had just go on forever. Fortunately it stopped not because anyone understood the arithmetic it is stopped for other reasons, but let us ask what if suppose the growth had continued then we would see here the thing that we just saw in the chessboard.

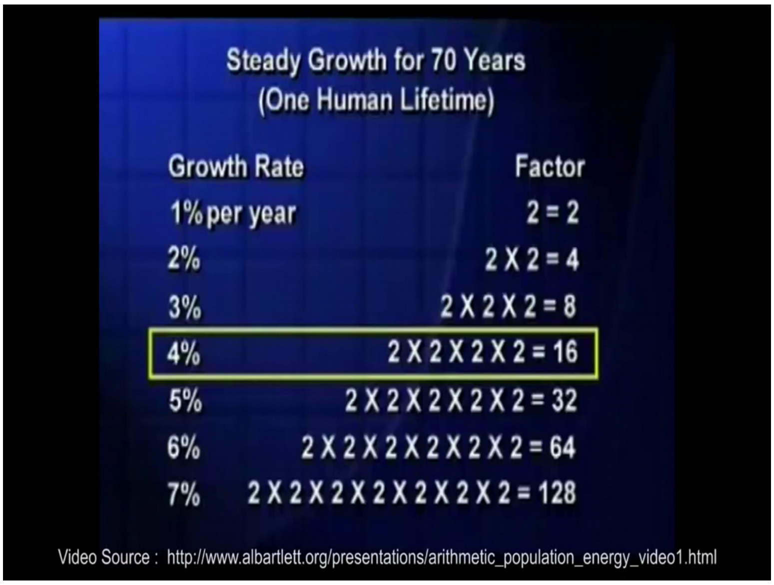
In the 10 years following the appearance of this ad in that decade, the amount of electrical energy that we would have consumed in this country would have been greater than the total of all of the electrical energy, we had ever consumed in the entire preceding history of the steady growth of that industry in this country. Now did you realize that anything is completely acceptable as 7 percent growth per year could give such an incredible consequence that in just 10 years you would use more than the total of all that have been used in all of preceding history?

(Refer Slide Time: 14:33)



Well that is exactly what president carter was referring to in his famous speech on energy; one of his statements was this he said and in each of those decades more oil was consumed than in all of mankind's previous history. Now by itself that is a stunning statement, now you can understand it the president was telling us a simple consequence of the arithmetic of 7 percent growth each year in world oil consumption and that was the historic figure up until the 1970s. Now there is another beautiful consequence of this arithmetic if you take seventy years as a period of time and note that that is roughly one human lifetime then any percent growth continued steadily for 70 years gives you an overall increase by a factor that is very easy to calculate.

(Refer Slide Time: 15:16)

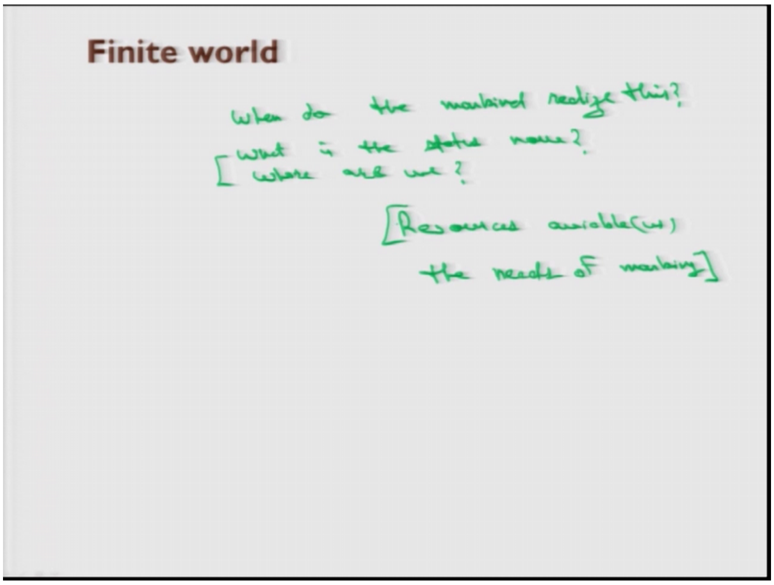


For example 4 percent per year you find the factor by multiplying four twos together it is a factor of 16. Now a few years ago one of the newspapers here in boulder quizzed the 9 members of the boulder city council and asked them what rate of growth of boulders population do you think it would be good to have in the coming years. Now the 9 members of the boulder city council gave answers ranging from a low of 1 percent per year now that happens to match the present rate of growth of the population of the united states we are not at zero population growth, right.

Now, the number of American's is increasing by more than 3 million people every year. No member of the city council said boulders should grow less rapidly than the United States is growing. Now the highest answer any council member gave was 5 percent per year, you know I felt compelled I had to write him a letter and say did you know that 5 percent growth for just 70, I can remember when 70 years used to seem like an awful long time it does not seem. So, long now well that mean boulders population would increase by a factor of 32 that is where today we have one overloaded sewer treatment plant in 70 years we need 32 overloaded sewer treatment plants. Now did you realize that anything is completely all American as 5 percent growth per year could give such an incredible consequence in such a modest period of time? Our city council people had zero understanding of this very simple arithmetic.

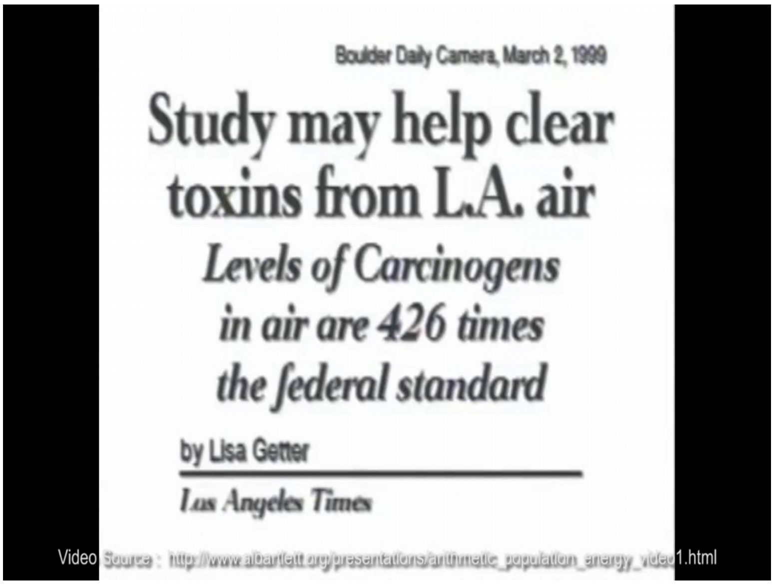
So, it was beautiful he explained it in a very good way a brilliant way that even the 7 percent of growth which looked like just 7 percent small figure; so, how it is affecting exponentially.

(Refer Slide Time: 17:15)



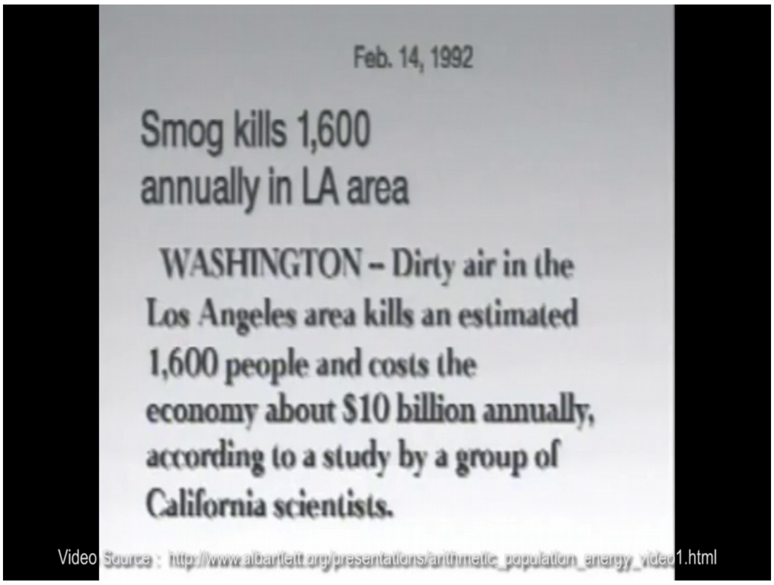
Now, the question is when did when do the mankind realize this. So, what is the status now or in other words where are we in terms of resources available versus the needs of mankind taking into account the population growth. For this I would like again Professor Al Bartlett to explain. So, let us move to the second part of the video in there like he would divide this time into 10 years. In the 10 years what is the population growth going on and where do we stand now? So, let us move to the second part of the video.

(Refer Slide Time: 18:55)



Here is an interesting headline from Los Angeles that headline probably has something to do with this headline.

(Refer Slide Time: 19:05)

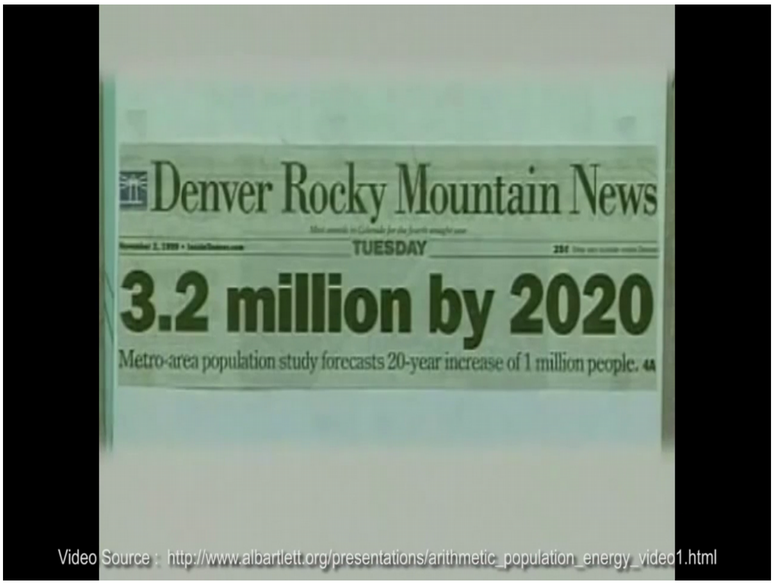


So, well how are we doing in Colorado, the Denver post tells us that we are the growth capital of the USA and proud of it the Rocky Mountain news.

(Refer Slide Time: 19:13)

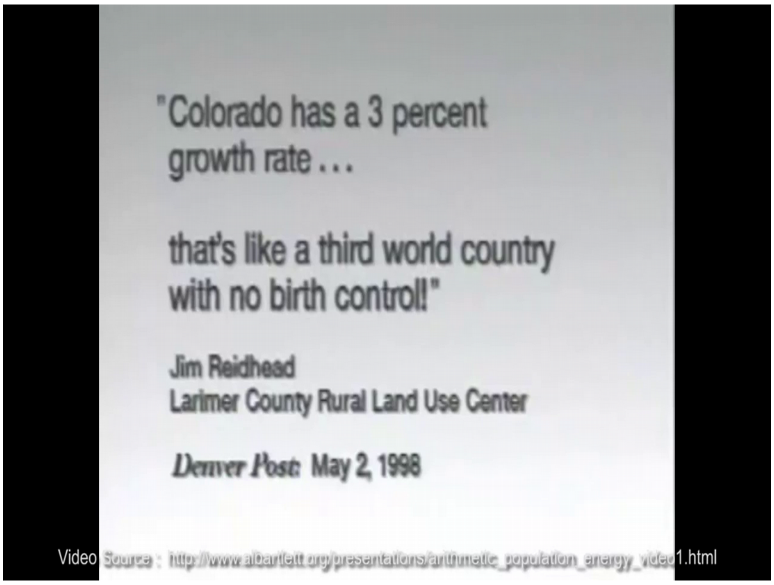
Tells us to expect another million people in the front range in the next twenty years, but in the post.

(Refer Slide Time: 19:20)



There was an interesting story someone was quoted as saying Colorado has a three percent growth rate.

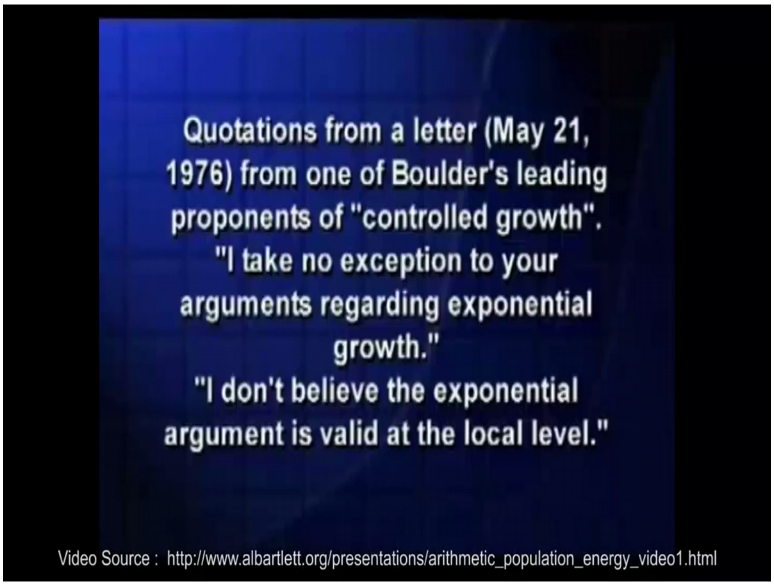
(Refer Slide Time: 19:30)



That is like a third world country with no birth control we send foreign aid family planning assistance to countries that have smaller population growth rates than Colorado has.

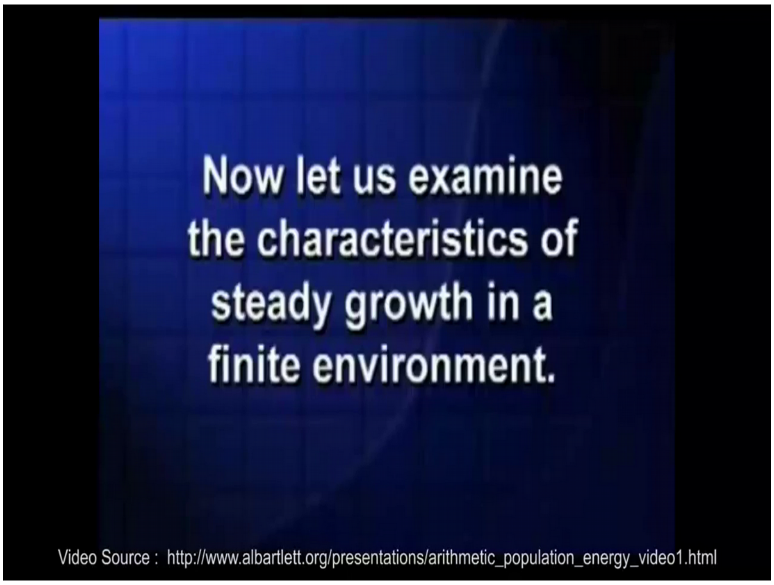
Well as you can imagine a growth control is very controversial and I treasure the letter from which these quotations are taken, now this letter was written to me by a leading citizen of this community, he is a leading proponent of controlled growth now control growth just means growth.

(Refer Slide Time: 20:08)



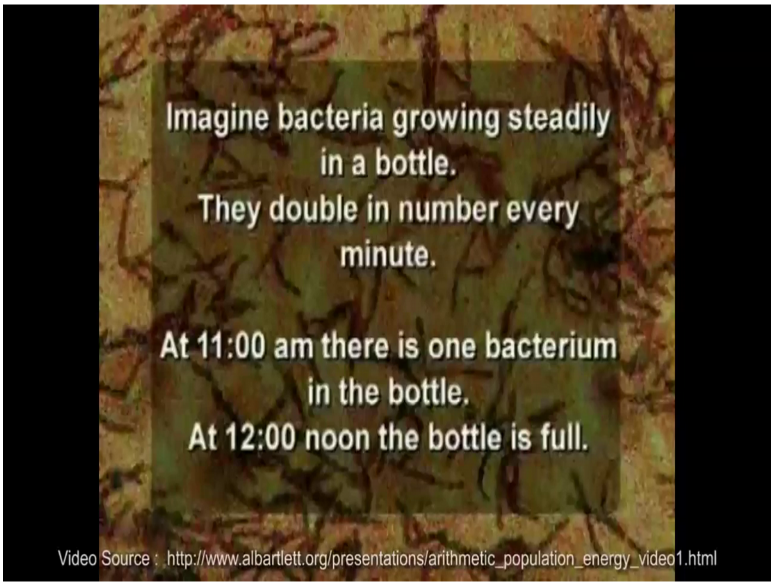
This man writes I take no exception to your arguments regarding exponential growth I do not believe the exponential argument is valid at the local level. So, you see arithmetic does not hold in boulder. Now I have to admit that man has a degree from the University of Colorado it is not a degree in mathematics in science or in engineering.

(Refer Slide Time: 20:39)



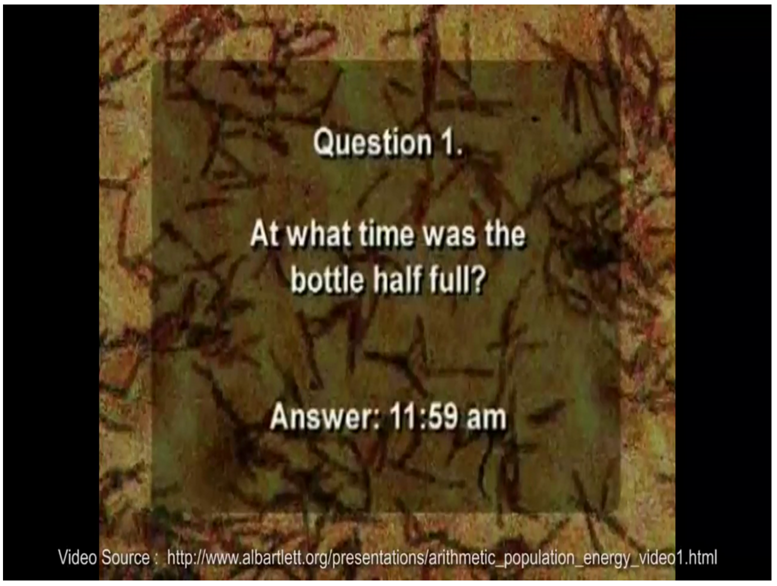
Let us look now at what happens when we have this kind of steady growth in a finite environment bacteria grow by doubling and one bacterium divides to become to the 2 divide to become 4 the 4 become 8 16 and so on.

(Refer Slide Time: 20:51)



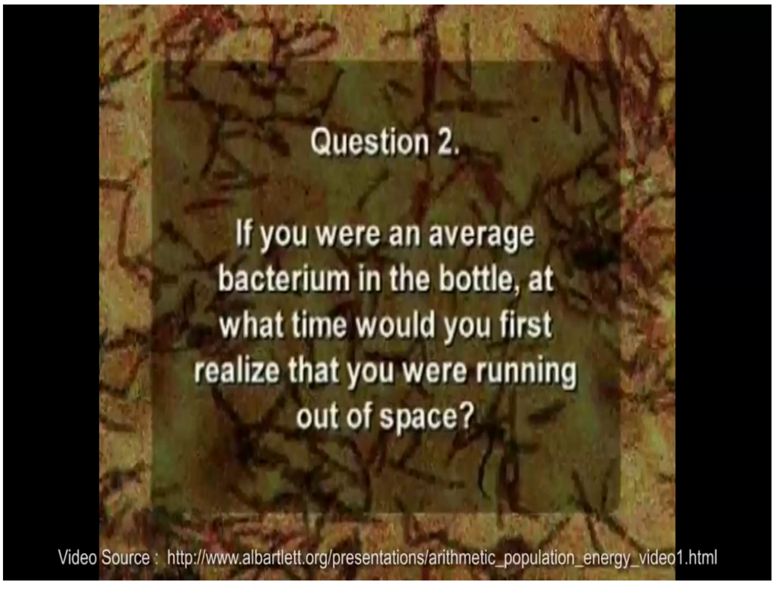
Suppose we have bacteria that doubled in number this way every minute suppose we put one of these bacteria in an empty bottle at eleven in the morning and then observe that the bottles fall at 12 noon. Now there is our case of just ordinary steady growth it has a doubling time of one minute it is in the finite environment of one bottle.

(Refer Slide Time: 21:07)



I want to ask you three questions number one at what time was the bottle half full well would you believe 11:59 minute before 12 because they double in number every minute and the second question.

(Refer Slide Time: 21:34)

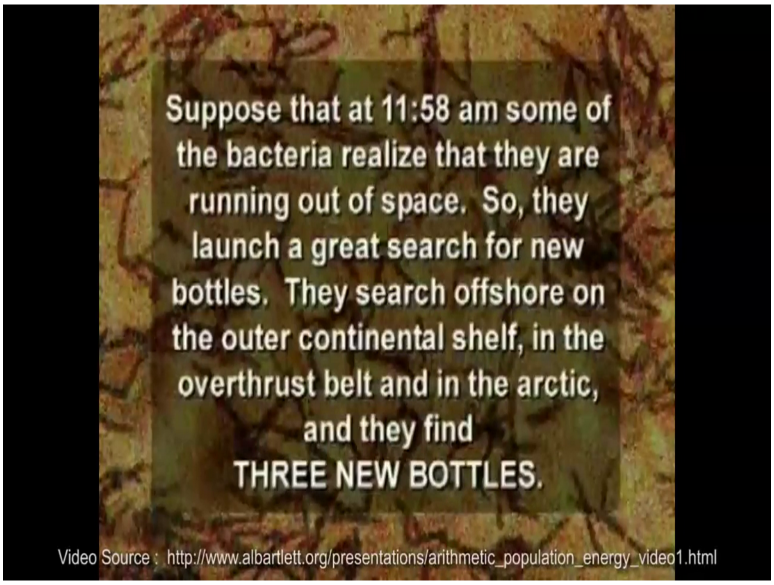


If you were an average bacterium in that bottle at what time, would you first realize that you were running out of space. Now think about this this kind of steady growth is the centerpiece of the national economy and of the entire global economy think about it.

(Refer Slide Time: 21:58)

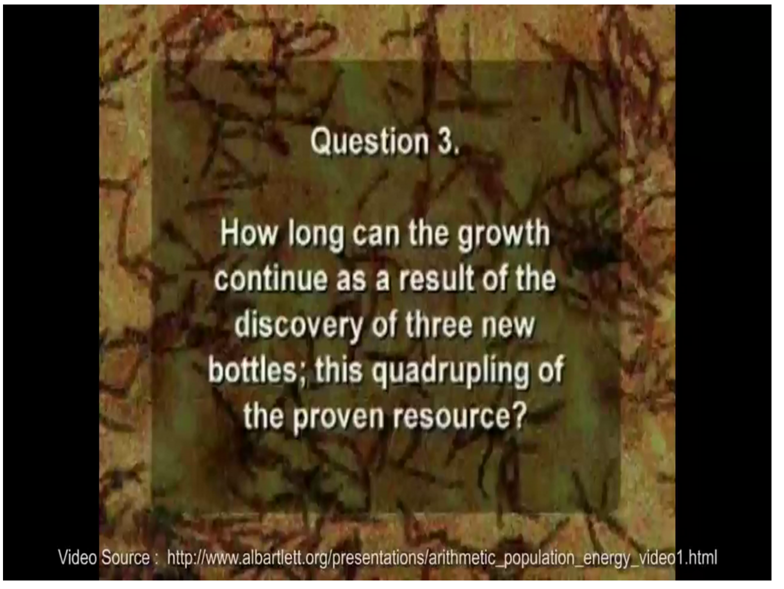
We'll let us just look at the last minutes in the bottle at 12 noon, its full 1 minute before its half full 2 minutes before it is a quarter full than an 8th and a 16th, let me ask you at 5 minutes before 12 when the bottles only three percent full and is 97 percent open space just yearning for development. How many of you would realize there was a problem? Now in the ongoing controversy over growth in boulder someone wrote to the newspapers some years ago and said look. There is not any problem with population growth in boulder because the writer said we have 15 times as much open space as we have already used. So, let me ask you what time was it in boulder, when the open space was 15 times the amount of space we had already used, the answer is it was 4 minutes before 12 in boulder valley.

(Refer Slide Time: 22:49)



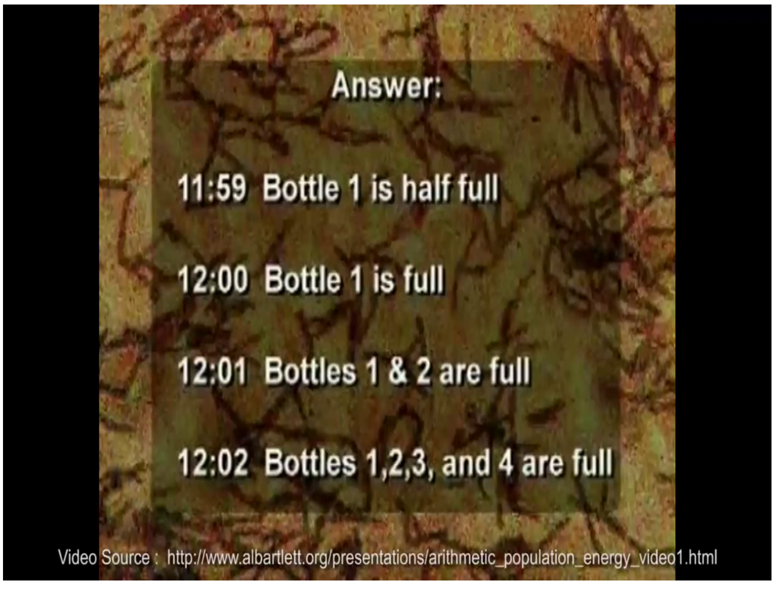
Well suppose it at 2 minutes before 12 some of the bacteria realized that there running out of space. So, they launched a great search for new bottles and they searched offshore on the outer continental shelf and the over thrust belt and in the arctic and they find three new bottles, now that is a colossal discovery that discovery is three times the amount of resource they ever knew about before, they now have 4 bottles before the discovery there was only 1. Now surely this will give them a sustainable society (Refer Time: 23:22) would you know what the third question is, how long can the growth continue as a result of this magnificent discovery well.

(Refer Slide Time: 23:26)



Let us look at the score at 12 noon one bottle is filled there are 3 to go 12 o1 2 bottles are filled there 2 to go, in a 12 o 2 all four are filled and that is the end of the line.

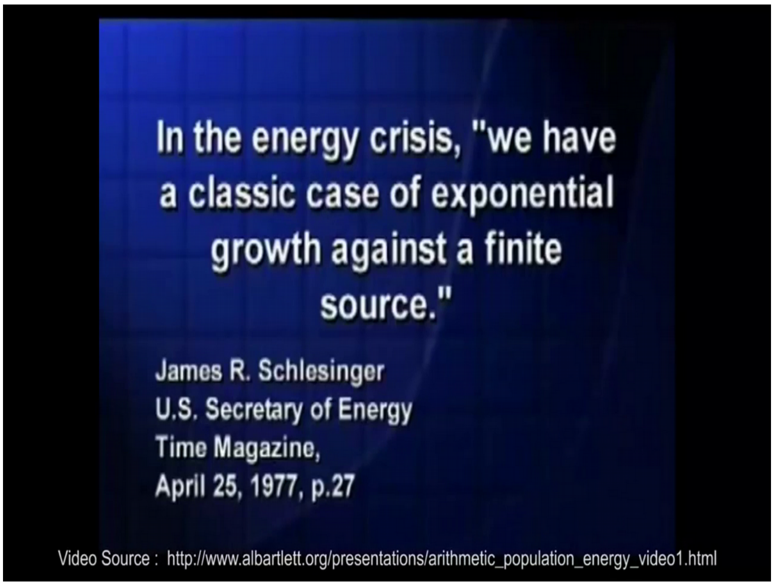
(Refer Slide Time: 23:30)



Now, you do not need any more arithmetic than this, to evaluate the absolutely contradictory statements we have all heard and read from experts who tell us in one breath, we can go on increasing our rates of consumption of fossil fuels in the next breath they say, but do not worry we will always be able to make the discoveries of new resources that we need to meet the requirements of that growth well some years ago in

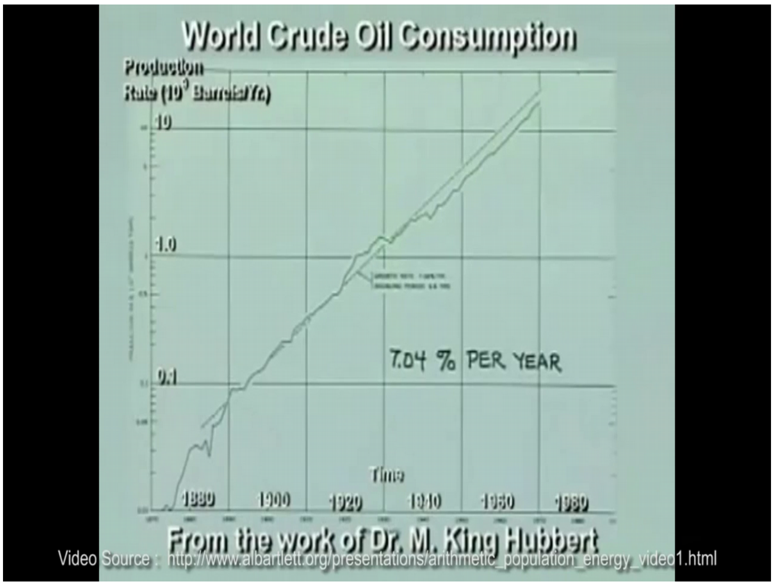
Washington our energy secretary observed that in the energy crisis we have a classic case of exponential growth against a finite source.

(Refer Slide Time: 24:12)



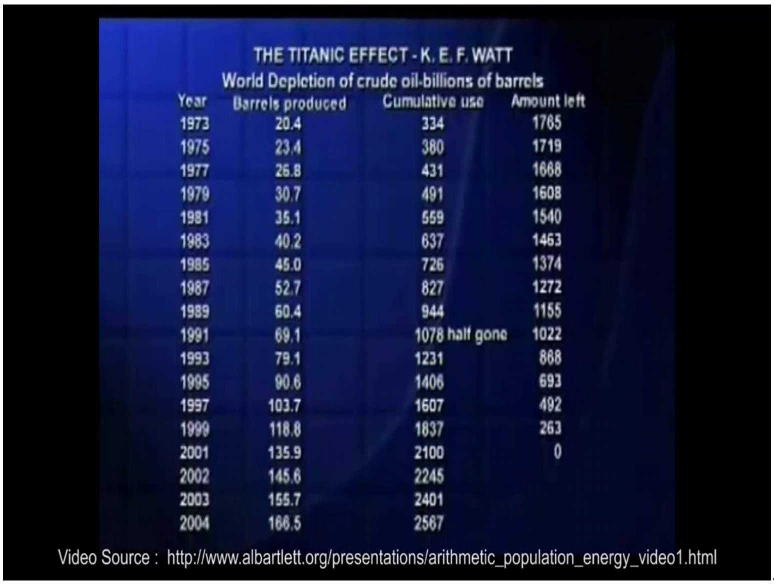
So, let us look at some of these finite sources from the work of the late Dr M King Hubert.

(Refer Slide Time: 24:17)



We have here is some logarithmic plot of world oil production, the lines been approximately straight for over a 100 years clear up here to the year 1970 average growth rate very close to 7 percent per year.

(Refer Slide Time: 4:49)


THE TITANIC EFFECT - K. E. F. WATT

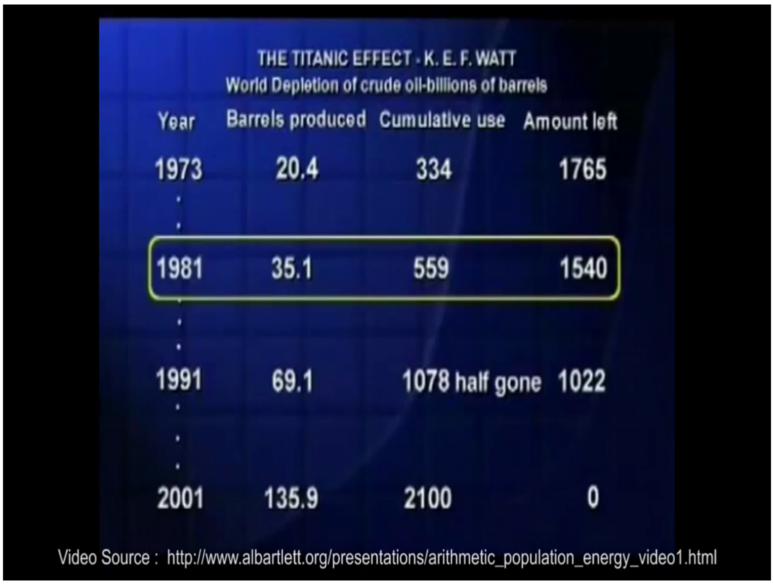
World Depletion of crude oil-billions of barrels

Year	Barrels produced	Cumulative use	Amount left
1973	20.4	334	1765
1975	23.4	380	1719
1977	26.8	431	1668
1979	30.7	491	1608
1981	35.1	559	1540
1983	40.2	637	1463
1985	45.0	726	1374
1987	52.7	827	1272
1989	60.4	944	1155
1991	69.1	1078 half gone	1022
1993	79.1	1231	868
1995	90.6	1406	693
1997	103.7	1607	492
1999	118.8	1837	263
2001	135.9	2100	0
2002	145.6	2245	
2003	155.7	2401	
2004	166.5	2567	

Video Source : http://www.albartlett.org/presentations/arithmetic_population_energy_video1.html

So, it is logical to ask well how much longer could that 7 percent continue. Well that is answered by the numbers in this table, in the top line the numbers tell us that in the year 1973, world oil production was 20 billion barrels the total production in all of history including that 20 was 300 billion the remaining reserves 1700 billion. Now those are data the rest of this table has just calculated out assume that the historic 7 percent growth continued steadily each year following 1973 exactly as it had been for the preceding 100 years now. In fact, the growth stopped, not because of the arithmetic it stopped because opec raised their oil prices. So, we are asking what if suppose the growth had continued.

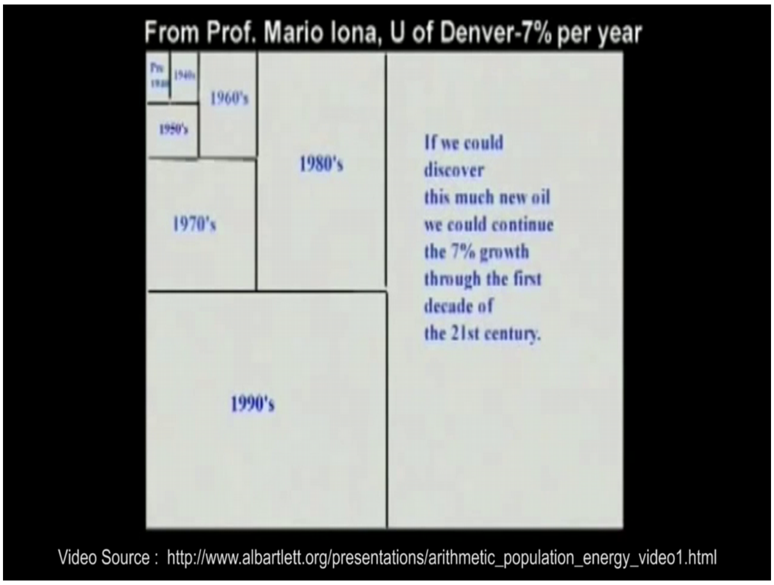
(Refer Slide Time: 25:33)



Let us go back to the year 1981. By 1981 on the 7 percent curve the total usage in all of history would add up to 500 billion barrels the remaining reserves 1500 billion. The reserves at that point are three times the total of all that have been used in all of history. That is an enormous reserve, but what time is it when the remaining reserve is three times a total of all you have used in all of history and the answer is 2 minutes before 12, well we know for 7 percent growth the doubling time is 10 years, we go from 1981 to 1991. by 1991 on the 7 percent curve the total usage in all of history would add up to a thousand billion barrels that be a thousand billion left at that point the remaining oil would be equal in quantity to the total of all that we had used in something like a 130 years of the oil industry on this earth. By most measures you would say that is an enormous remaining reserve, but what time is when the remaining reserve is equal to all that you have used in all of history and the answer is its 1 minute before 12.

So, we go one more decade to the turn of the century that is like right now, that is 17 percent would finish using up the oil reserves of the earth. Now let us look at this in a very nice graphical way.

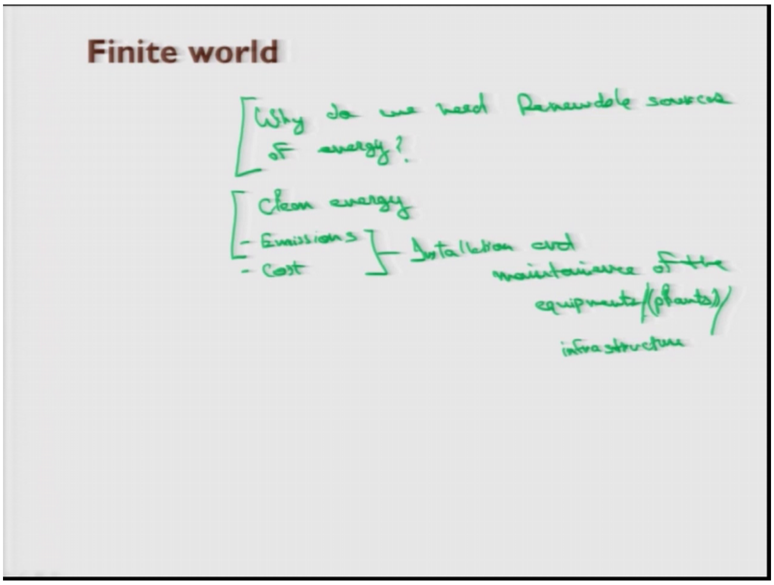
(Refer Slide Time: 26:56)



Suppose the area of this tiny rectangle represents all the oil, we used on this earth before 1940 then in the decade of the forties we use this months that is equal to the total of all that have been used in all of history. In the decade of the fifties we use this much that is equal to the total of all that have been used in all of history, in the decade of the sixties we use this much and again that is equal to the total of all the preceding usage. Now here we see graphically what president carter told us.

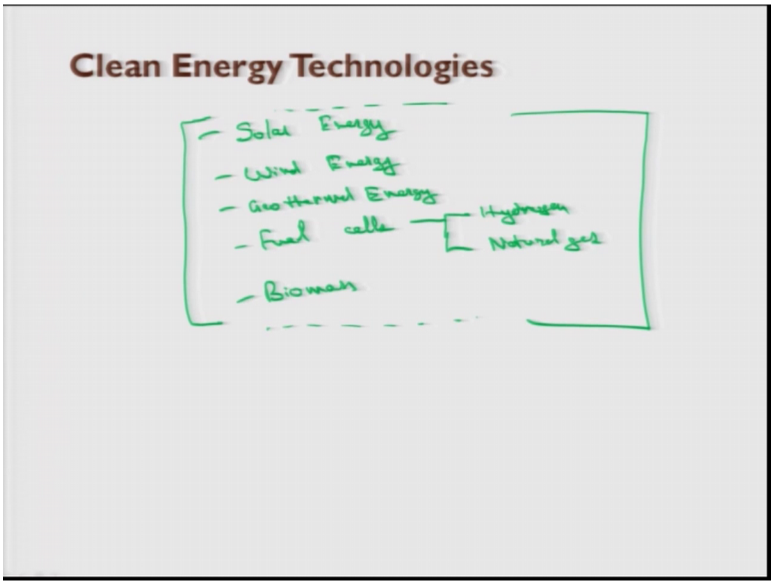
Now, if that 7 percent had continued through the seventies, eighties and nineties there is what we need, but that is all the oil there is. Now there is a widely held belief that if you throw enough money at holds in the ground oil is sure to come up. Well there will be discoveries in new oil there may be major discoveries, but look we have to discover this much new oil if we would have that 7 percent growth continue 10 more years. Well ask yourself what do you think is the chance that oil discovered after the close of our class today will be in an amount equal to the total of all that we have known about in all of history, and then realize if all that new oil could be found that would be sufficient to let the historic 7 percent growth continue 10 more years.

(Refer Slide Time: 28:29)



So, I think this very well explains why do we need renewable sources of energy. So, besides saving the non-renewable or finite resources of energy, renewable sources also helps us to give clean energy that is emissions though there are emissions and cost that is associated with installation and maintenance of the equipments, I would say maybe maintenance of the equipments or plants, here by plant I am trying to say is this solar or wind energy plants or solar energy parks or in the further terms infrastructure; however, other missions which are due to the use of non-renewable resources are less for example, coal, petroleum those are all non-renewable resources and here we have the clean sources of energy.

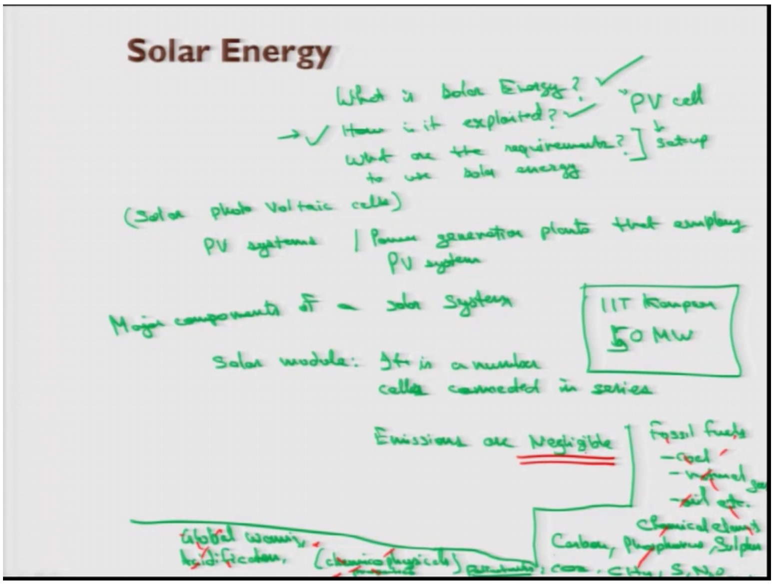
(Refer Slide Time: 30:12)



So, what are these clean sources solar energy, wind energy then I have geothermal energy, then we have fuel cells, these fuel cells may be hydrogen fuel cells or may be natural gas fuel cells then also we have biomass these are clean energy technologies.

So, we will see how does these technologies work and what is the status in the present time what is solar energy question is what is solar energy.

(Refer Slide Time: 31:14)



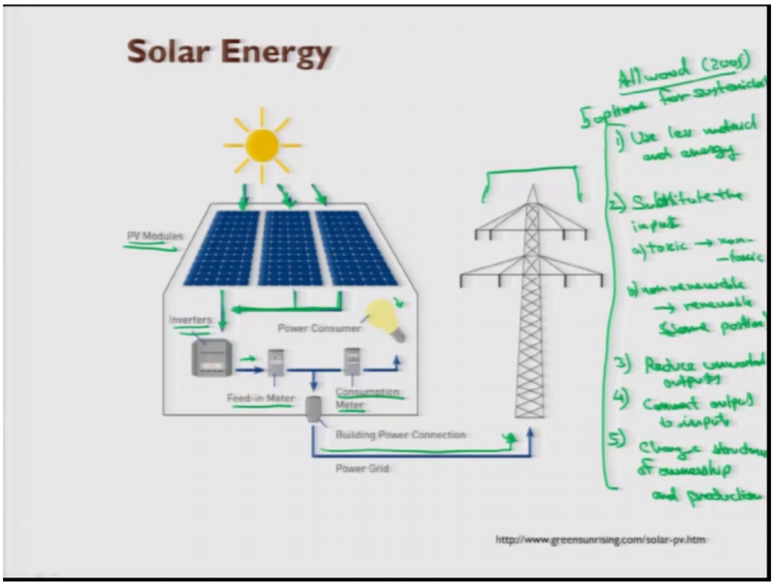
How is it exploited what are the requirements to use solar energy. So, the answer to the first question is solar energy is the energy that is provided by sunlight the amount of sun that hits our country that hits India is enormous, we live in South Asia and the amount of sun hits here is very good in the countries in maybe in North America and some places the sunlight does not come very openly. So, here we have a great opportunity to exploit to use to harness this solar energy for a positive cause.

So, how is it exploited we need to have PV cells photovoltaic cells what are these cells I will just discussed, what are the requirements we need to have a a set up to convert this solar energy into electric energy tend to use it wherever it is required. So, solar photovoltaic cells or the short name it is known as PV. PV cells better I would call it PV systems PV systems are the most popular solar technology that is employed in power generations there are power generation plants, that employ PV systems in IIT, Kanpur also; we have a 50 megawatt solar plant of capacity 50 megawatt. Now the major component of PV systems are. So, how is it exploited I am talking about the second question here.

Major components of a solar system we need to have a solar module, what is a solar module? It is a number of cells those are connected in series number of cells connected in series. So, the solar photovoltaic power system produces negligible emissions the emissions here are negligible. So, in comparison to the other fossil fuels for example, fossil fuels are the other fossil fuels are coal, fossil fuels like coal, natural gas, oil etcetera they contain number of chemical elements including these elements are may be carbon, phosphorus, sulfur. So, burning fossil fuels in electricity production leads to a generation of emissions. So, these emissions are not good for environment.

So, these they pro have pollutants such as carbon dioxide, methane, sulfur, nitrogen oxides and so on. So, these pollutants are here in case of folio fossil fuels and these emission are released into environment which are which have damaging effects on global warming. So, the bad effects here are global warming then acidification of the environment then eutrophication that that call. So, be there the level of severity of environment impact depends upon the amount of emissions, that is these emissions have chemical and physical properties, these pollutants have chemical and physical properties I would use a word chemico physical properties here. So, these effect. So, in case of our solar energy or in case of clean energy these all are not there these emissions are not there. So, the emissions are negligible in case of solar cells in case of solar energy.

(Refer Slide Time: 37:48)

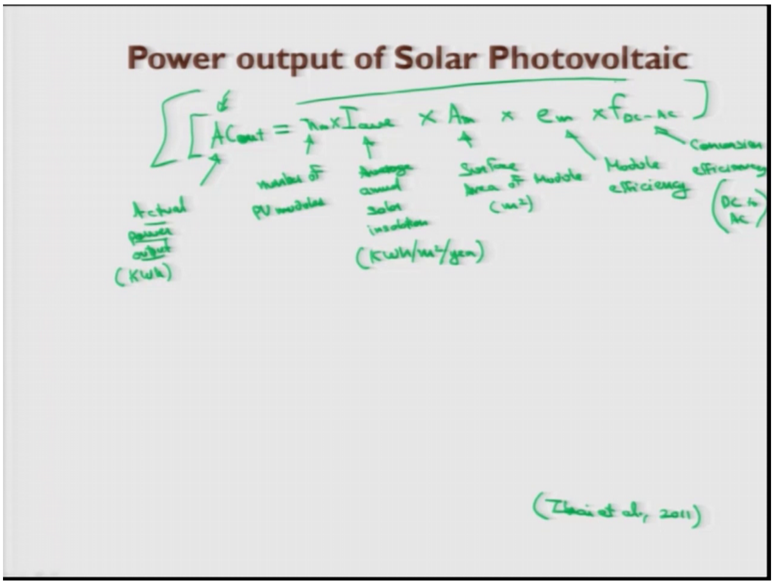


So, this is one of this solar energy setup. So, in this case what is happening we have PV modules over here, the sunlight is falling on these PV modules and the energy is being generated and stored in the inverters here. So, these inverters are charged and keep the energy. So, there are there is a battery to store energy here. So, this energy can be used in various ways. So, maybe feed in meter consumption meter is there that is telling what is the energy. So, this energy is going to our power grid also here. So, this is power the consumer is using and even commercially also this can be used. So, this is taken from a reference here. So, in domestic use the solar energy can be used to fulfill the needs, but in case of industrial use the solar energy cannot the infrastructure is not this much available that, it can fulfill the whole needs of the industry in the present time.

So, there is a study by Allwood in in this regard it was conducted in 2005, he says that there are 5 options for sustainability. Number 1, he said use less material and energy number 2 he says substitute the input materials substitute the input I would say that is he says go from toxic to non-toxic, go from non-renewable to renewable that is some part some portion of energy. I would say also the other thing he suggested we had been discussing those were reduced unwanted outputs convert outputs to inputs and change structures of ownership and production, that is change the structure of supply chain product service system ownership and production.

So, I would suggest to read this study. So, how the power output from solar for voltaic cells is calculated.

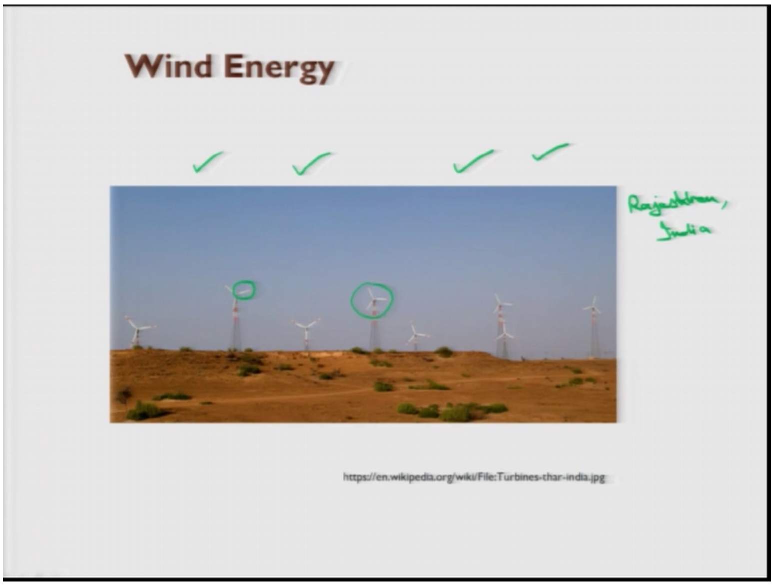
(Refer Slide Time: 41:31)



So, the power is ac I would put air output power that is proportional to the average annual solar insolation I would say I, average I will put the details here then it is also proportional to the area of one PV module, area of PV module here and module efficiency and I would say here a factor that is from DC to AC conversion efficiency. So, this is it is total AC output that is power consumed is proportional to this one. So, this is for 1 PV module. So, if I put here my number of PV modules here. So, I could put an is equal to sign here. So, in this case this is my actual power output that is in maybe if I say kilowatt hours, then this is number of PV modules, I is my average annual solar insolation that is per year this can be in kilowatt hour per meter cube per year, then A is my surface area of module.

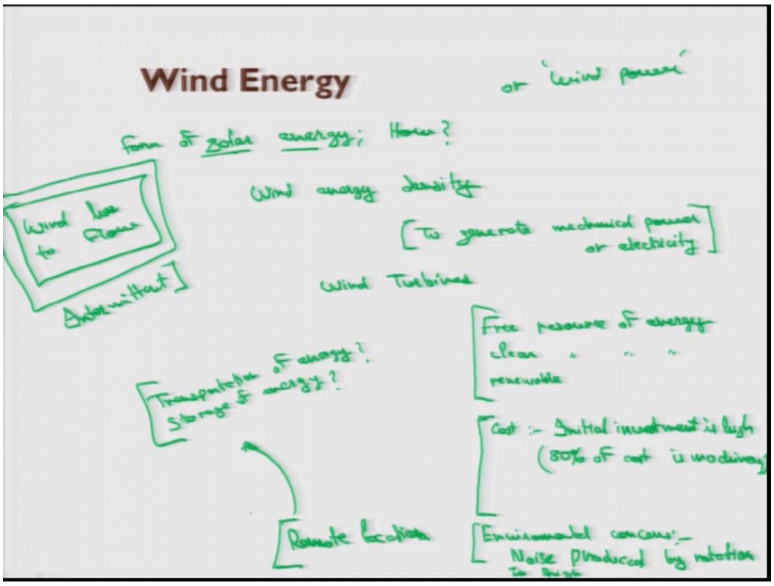
So, this surface area would be in meter square, em is my module efficiency and this one is the conversion efficiency that is conversion insufficiency from DC to AC. So, this relation was given by Zhai and others Zhai et al in 2011. So, they developed this relation and helped us to calculate the output power for a solar plant. So, with this I would come to my next energy.

(Refer Slide Time: 45:19)



That is wind energy. So, this is one kind of wind Energy Park in Rajasthan India it is taken from a reference.

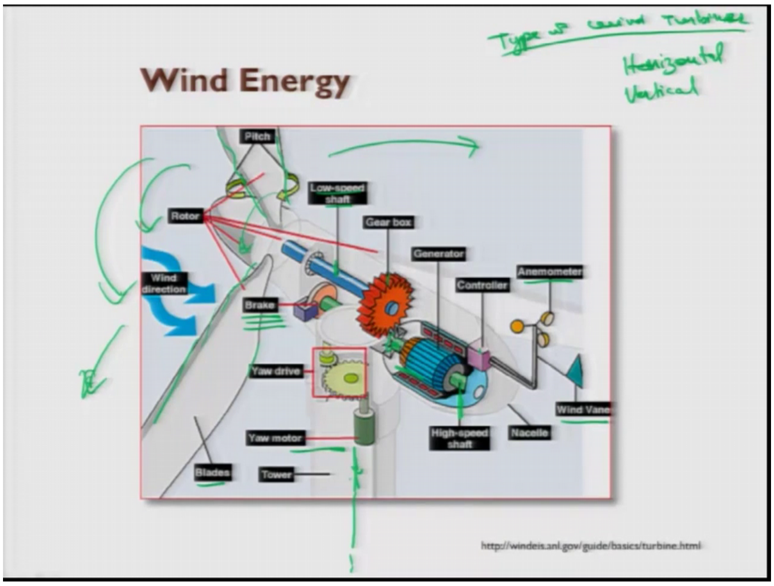
(Refer Slide Time: 45:41)



So, what is wind energy? Wind is another soft source of energy only it is actually the form of solar energy only. So, because it is a kind of I would say it is a form of solar energy how because the wind is generated by uneven heating of the earth surface and sea shores, the uneven heating would let the wind to pass from the higher pressures to lower pressures. So, because of the heating the pressure rises and the wind flow.

So, that is why the wind flows it is if again the sun is playing its role in producing wind. So, wind energy sources are geographically dependent on the local resources, measurement of wind energy resources can be made by using wind energy density. So, the terms here wind energy or wind power what does these represent? These describe the processes by which the wind energy or the flow of the wind can be used to generate mechanical power or electricity, to generate this is the purpose here. So, for this what is required we need to have wind turbines. Wind turbines are like the aircraft propeller blades.

(Refer Slide Time: 47:49)



So, this is our turbine here. So, these are the blades I can show this schematic here. So, this is these are my blades they are just like aircraft propeller and they turn in the moving air the when air is coming, these keep on turning these key starts rotating here and an electric generator is connected to this one this is my generator. So, this is actually the speed is not very fast. So, that is why a gearbox is here sorry the gear ratio here is such that the speed of the motor is much larger than the rotation speed of the turbines and these turbines this fins are of large size and this turbines rotate our generator and electricity is produced and controller is there and this electricity can be further stored into a cell. So, we have a break here as well in case of in case we need to stop the job motor is there to like maybe if we need to convert it into mechanical energy then we have tower blades.

So, this is it has given very clearly this is a low speed shaft and this is gearbox head. So, this becomes our high speed shaft this portion this becomes our high speed shaft. So, anemometer and wind when vane are there to control this rotation of our turbine, that is along this axis. So, they could even tell the direction of the wind. So, this is how our wind turbine setup is there. So, wind turbine types may be horizontal or vertical these are types of wind turbines. Then it also depends upon the local conditions that what kind of turbine can be installed. So, in general the most large modern wind turbines are horizontal axis turbines only. So, this is a kind of horizontal axis turbine this also is a horizontal axis turbine these are all horizontal axis turbines here.

So, wind energy is again the free resource of energy also it is clean resource of energy it is renewable. So, these are the benefits. So, clean nonpolluting electricity can be obtained using wind energy, but there are certain issues as I discussed the cost of installation is high the initial investment is high initial investment I would say is high. So, here approximate 80 percent of cost is machinery. So, I will discuss the cost benefit analysis after discussing these clean technologies. So, environmental concerns are there. So, a little light on the environmental concerns.

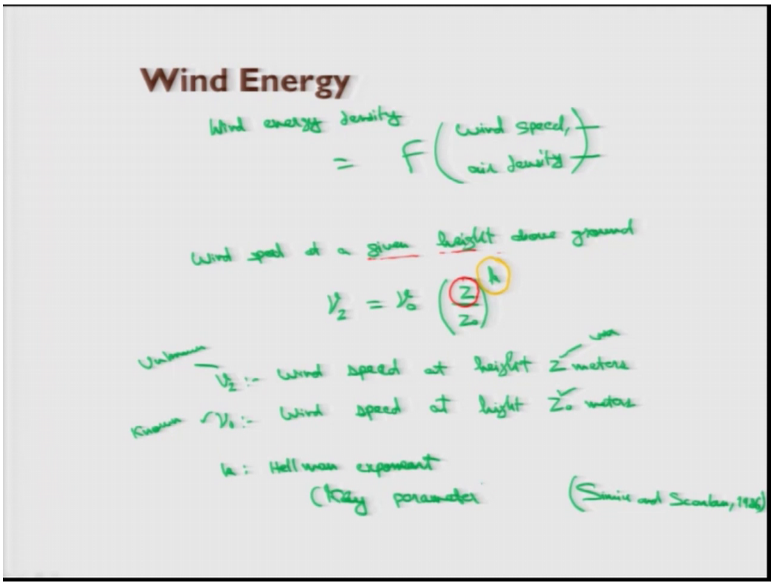
So, though it is a clean energy and the wind power plants have very little impact only when environment compared to the fossil fuel that fossil fuel power plants, there are some concerns over the noise that is produced. Thereby environmental concerns I would say the noise produced by the rotation of blades is noise produced by rotation is high and there are aesthetic or visual impacts that is the birds and bats having been killed by this one these rotating blades by like by flying into the rotors. So, these kind of environmental impacts into the habitat also are there. So, most of these problems have been resolved or greatly reduced through technological development these days by properly sighting the wind plants, properly sighting means it is generally sited at remote locations.

Otherwise the noise that is produced by the wind turbines is not acceptable in the domestic or in the living areas. So, the supply and transport issues are here because the wind plants are only at the remote locations. So, here come the problem of transportation of energy. If cannot be transported then storage of energy how do we store this energy there are problems in this. So, the major challenge in using wind as a source of power is that it is intermittent the energy is intermittent it is only generated when wind flows the question is wind has to flow this is the major issue only when wind flows the energy can be produced.

So, this does not always allow to blow when electricity is needed; although wind generated electricity can be, but if batteries are used, but wind cannot be stored and not all winds can be harnessed to meet the timing of electricity demands and further because these are located in remote locations that are far from the electric power demand such as cities etcetera finally, the wind resource development may compete with other uses of the land and those alternative uses may be more highly valued than electricity generation.

So, the wind turbines can also be located on the land that is used for grazing or even farming. So, at those places it can be used. So, let us put some light on the wind speed at a specific location. So, wind energy density is the function of wind speed or air density at a specific location.

(Refer Slide Time: 55:11)

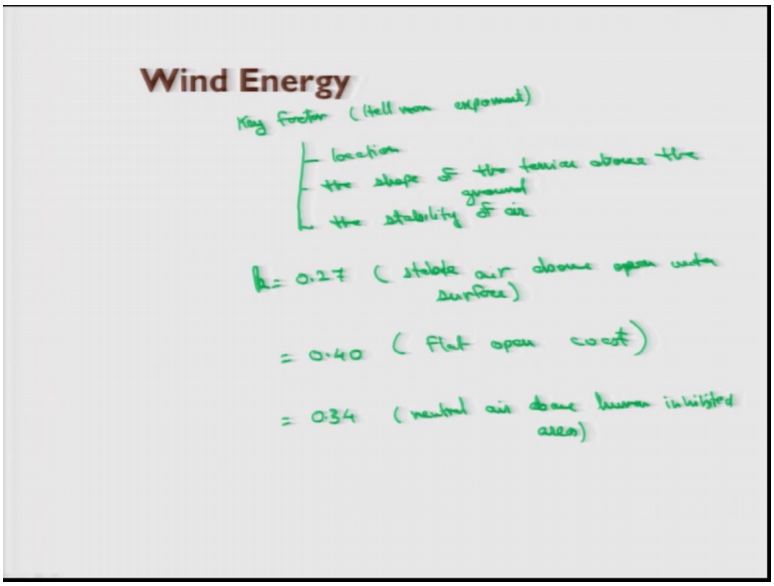


So, I would like to put here the wind energy density is proportional to wind speed and is also proportional to air density, I would not say proportional I would say it is related to this one or this one is a function of wind speed and air density.

So, wind speed vary with the height above the surface of earth and these 2 parameters jointly determine the wind energy density. So, wind speed at a given height above the ground can also be calculated using a relation, wind speed at a given height above ground can be obtained by a transformation that was given by Simiu and Scanlan in 1996. So, they say that this wind speed is equal to wind speed that is known at a specific location and that is at specific location z naught and there is a Hellmann exponent over here that is k. Here vz is our wind speed that we need to determine this is wind speed at height that is height we need to determine here is said this height we need to determine it is given height or to know what a given height this we need to determine.

So, wind speed at height z. I would say meters now v naught is wind speed at height z naught meters that is known. So, this is known this is unknown this height is known sorry this speed is unknown here and this speed is known. Now what is the deciding factor here. So, if you see the deciding factor that is here is our this exponent here. So, what is this this k is Hellmann's exponent and its value this is a key parameter here I would put here this is a key parameter here that determines this wind speed.

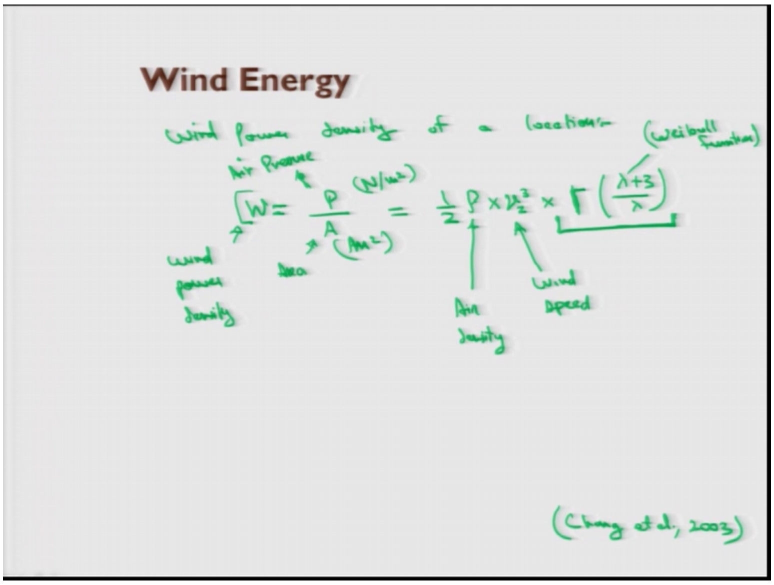
(Refer Slide Time: 59:10)



So, this Hellmann exponent is a key factor here that is Hellmann exponent. Now it depends upon certain factors what are those factors the location and the shape of the terrain above the ground also the stability of fear. Now the typical values of this factor for example, if it is a stable aware air above open water. So, source this k value is equal to 0.27 some typical values.

So, this is stable air above open water surface. So, the point of interest here is the flat open area for the flat open coast for example, if I say flat open coast its value is equal to 0.40. For human inhabited areas its value is 0.34 that is neutral air above human inhabited areas. So, here we can see how we can calculate the wind speed.

(Refer Slide Time: 61:42)



Now to find the wind energy another relation was given by Chang et al in 2003 who said that wind power density of a location can be calculated using an expression in which we have P by A. So, this P is simply my air pressures in newton per meter square this is my area in meter square. So, this can be detailed further as one by 2 rho times wind speed at that location to the third degree and a gamma function is involved here in which we have lambda plus 3 over lambda. So, here this is my wind power density this; what is this rho this is my air density this we know is pressure that is air pressure and this is the area.

Now, this is again wind speed and this gamma function has a lambda that is a Weibull factor it is a Weibull function which is dimensionless. So, this is the key factor here which determines our wind energy. So, we will not go into details because this goes out of the ambit of this course to discuss the gamma function and this lambda; however, we have a relation to determine the wind power density. So, with this I would like to take a break here and we will discuss fuel cells geothermal energy and biomass energy in the connecting session.

Thank you.