Advanced Green Manufacturing Systems

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Lecture – 29
Design for Environment (Part 1 of 4)

Good morning. Welcome back to the course. In this lecture I will talk about Design for Environment. We have talked about the algorithms analysis of variance and I have talked about the quality function deployment and value engineering the fewest lectures. So, I will take this course forward while discussing Design for Environment in this lecture.

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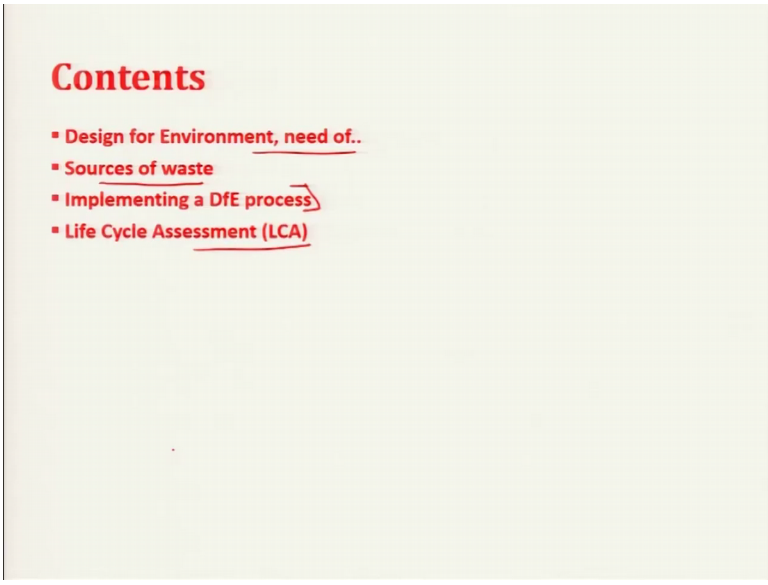

So, the contents are, first we will see what is the need of design for environment then we will see the sources of waste, then we will see how to implement the DfE Design for Environment.

Then we will see what is life cycle assessment which is essentially one of the techniques to conduct or to implement design for environment? Design for environment I can say is an apt tool or methodology. That is that acts as an umbrella under which various methodologies like lean manufacturing, green manufacturing, life cycle assessment is an essential part here this things comes into play.

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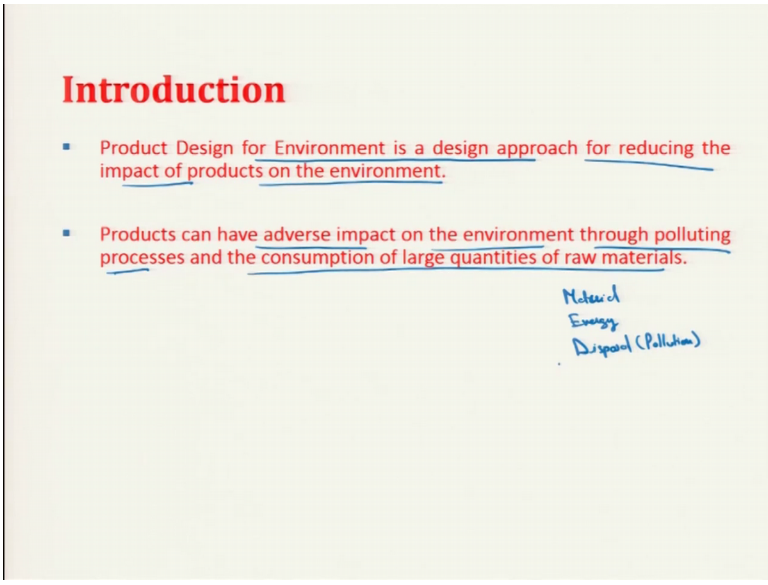

So, what is design for environment? Product design for environment is a design approach for reducing the impact of products on the environment. This is something understood definition what it says the products can have adverse impact on the environment through polluting processes and the consumption of large quantities of raw materials. So, the impact can be adverse also due to consumption of large amounts of energy and difficulties in disposal. So, as I said this material, energy and disposal or I could say pollution.

So, because of this the manufacturing concerns have to consider the products entire life from the creation of the product to the final disposal. So, in this life cycle there are many events of creating pollution maybe recycling, remanufacturing, reusing, reducing waste, refusing to use some of the unnecessary functions or the processes. So, these things should come into play.

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Now, product design for environment is a contemporary topic because people talking about the green manufacturing products. And also we will discuss the life cycle assessment. Life cycle assessment is the term that came late after Life Cycle Analysis LCA was first called LCA with that is life cycle analysis. Now it is known as life cycle assessment which involves life cycle inventory analysis or inventory management tools. Many other tools have come into play that is complete assessment earlier to was just the life cycle analysis.

So, we will discuss various software tools also the online tools those are available and the offline tools which are free versions and some purchases versions are also there. Several researchers all over the world are busy attempting to design product that minimise the impact on environment, why is it so. We have discussed that is a need to mitigate the environmental affects of manufacturing I would like to show you illustration here.

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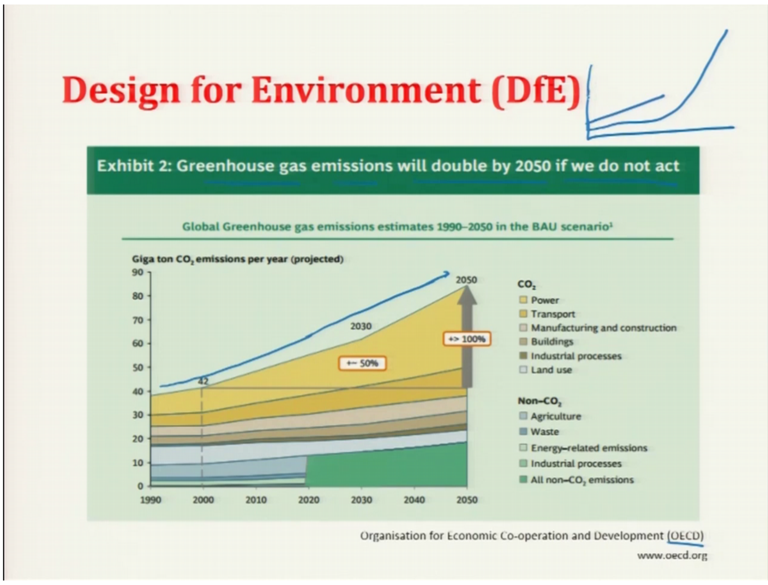

That is given by OECD, Organisation for Economic Cooperation and Development. So, they say that greenhouse gas emissions will double by 2050 if we do not act. If you see this is a prediction or the future forecast, it is going in this direction, at 2050 it has stopped. So, what is this going, would it just go parallel like this or would it go something like this. Let us try to see this, that where are we moving to.

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For this I would like to see this video that is given by Professor Al Bartlett who is no more. He was a pioneer professor who in 1969 gave a very celebratory talk on the arithmetic population and energy. He used the mathematical, arithmetical tools or calculations to show that how population is increasing and what are the resources that are available now and where we are leading to.

So, let us see this video, I would have shown actually shown this video well in the start of the course itself. But let us see this video to have a feel that where are we moving to and what is the need of design for environment.

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 and what I hope to do is I hope to be able to convince you.

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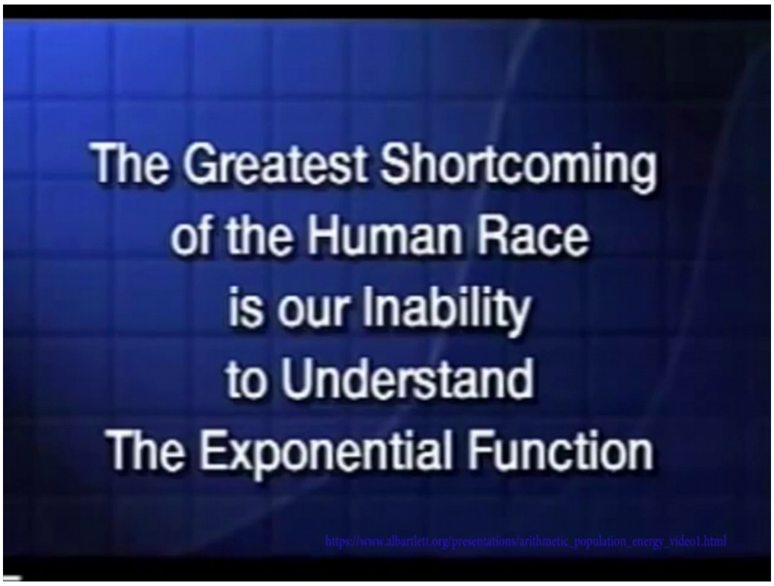

That the greatest shortcoming of the human race is our inability to understand the exponential function.

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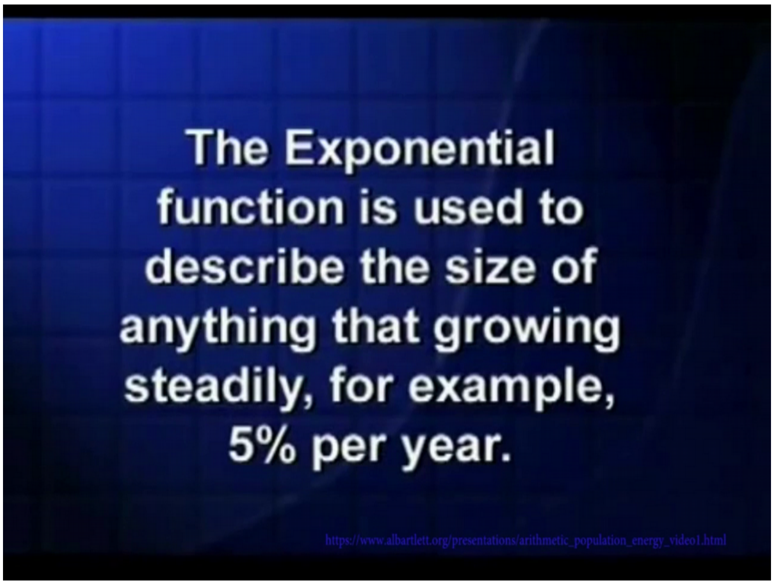

So, you say well what is the exponential function? This is a mathematical function that you would write down if you are going to describe the size of anything that was growing steadily. If you had something growing 5 percent per year, you would write the exponential function to show how large that growing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

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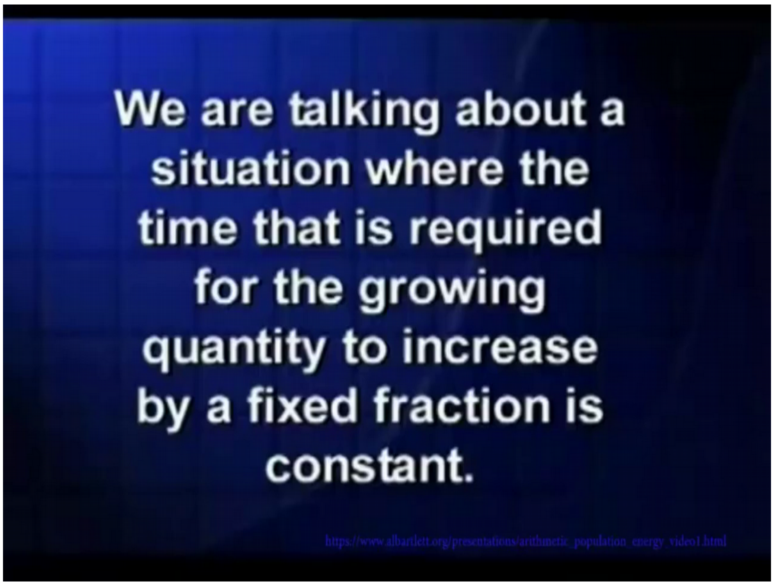

And so, we were talking about a situation where the time that is required for the growing quantity to increase by a fixed fraction is a constant 5 percent per year, the 5 percent is a fixed fraction, the per year is a fixed length of time. Now, that is what we want to talk about, its ordinary steady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

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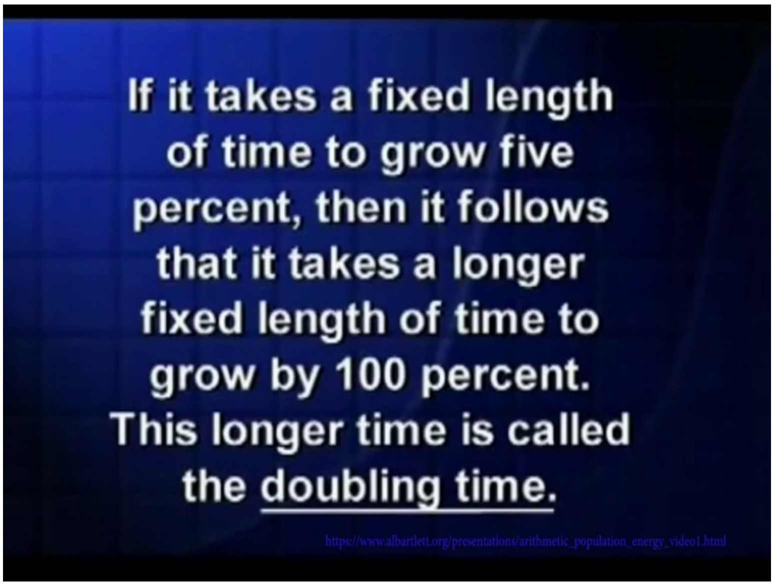

But if it takes a fixed length of time to grow 5 percent, it follows it takes a longer fixed length of time to grow a 100 percent. Now, that longer time is called the doubling time. We need to know how you calculate the doubling time and it is easy.

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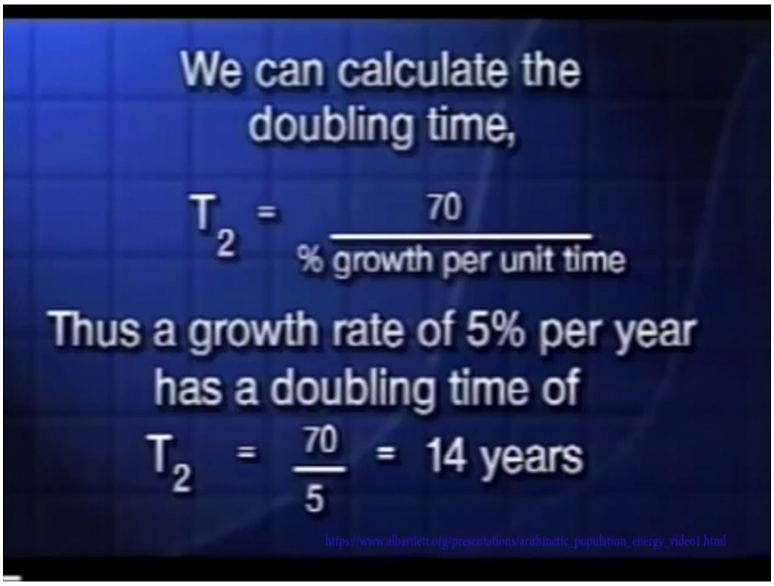

You just take the number 70 divided by the percent growth per unit time and that gives you the doubling time for example, of 5 percent per year, you divide the 5 into 70. You find that growing quantity will double in size every 14 years.

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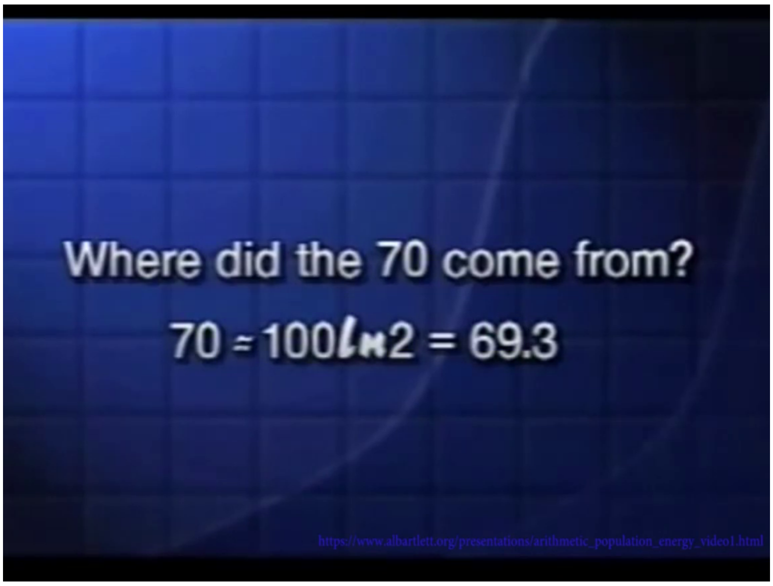

Well you might ask where did the 70 come from? The answer is it is approximately 100 multiplied by the natural logarithm of 2. If you wanted the time to triple reduce the natural logarithm of 3. So, it is all very logical, but you do not have to remember where it came from if you just remember 70.

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 say a headline that says crime is 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 7 percent really means? Let us take another example from Colorado, the cost of an all day lift ticket to ski at Vail.

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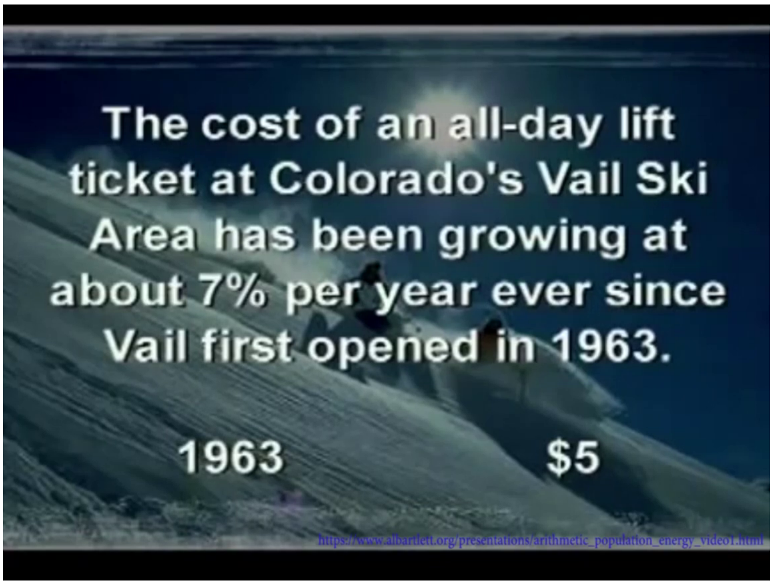

Has been growing about 7 percent per year ever since Vail first opened in 1963 and at that time you paid 5 dollars for an all day lift ticket. Now, what is the doubling time for 7 percent growth, 10 years.

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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 of something that is growing steadily.

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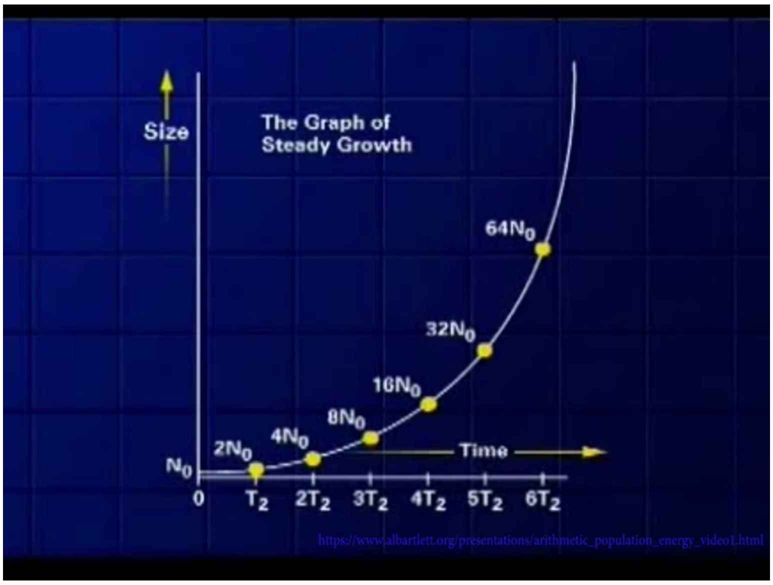

After 1 doubling time the growing quantity is up to twice its initial size, 2 doubling times, it is up to 4 times its initial size. Then it goes to 8, 16, 32, 64, 128, 256, 512. In just 10 doubling times it is a 1000 times larger than when it started and you can see if you try to make a graph of that on ordinary graph paper the graph will go right through the ceiling.

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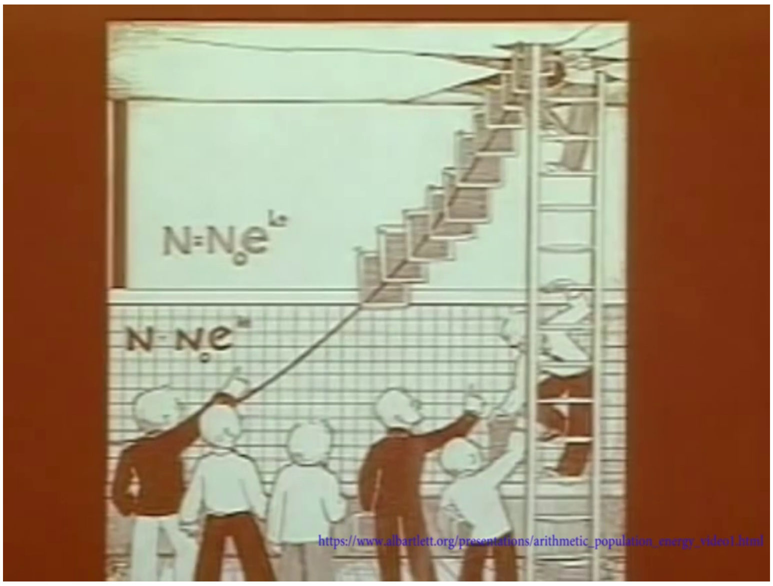

Now, let me give you an example to show the enormous numbers you get with just a modest number of doublings. Legend has it that the game of chess was invented by a mathematician to work for a king. The king was very pleased, he said I want to reward you and the mathematician said my needs are modest.

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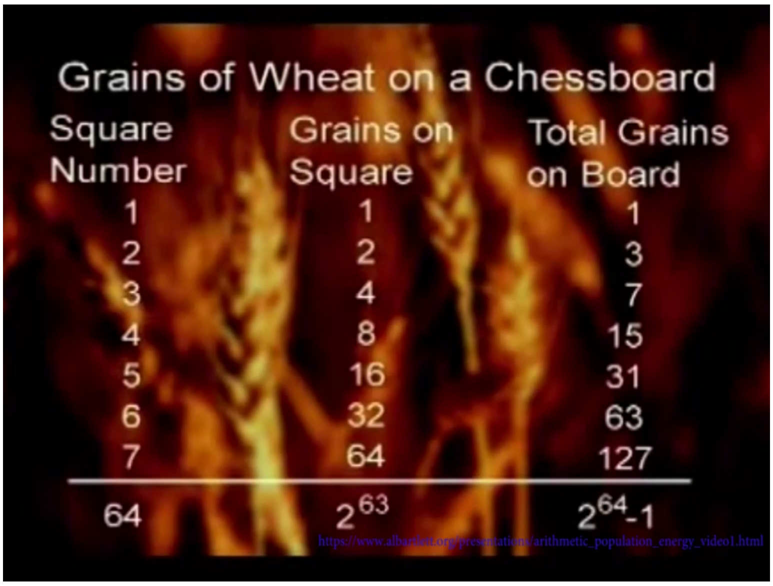

Please take my new chess board and on the first square place 1 grain of wheat. On the next square double the 1, they make 2. On the next square double the 2 to make 4. Just keep doubling till you double for every square that will be an adequate payment.

Well we can guess the king thought this foolish man. I was ready to give him a real reward. All I asked for, just a few grains of wheat. Well, let us see what is involved in this. We note there are 8 grains on the 4th square. Now, I can get this number 8 by multiplying 3 2s together. It is 2 times 2 times 2, it is 1 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 to 2s together.

Now, let us look at the way the totals build up and we have 1 grain on the first square, 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, is a grain less than 3 2s multiplied together.

15 is a grain less than 4 2s multiplied together. Well, that continues in each case. So, when we are done.

The total number of grains have been one grain less than the number I get multiplying 64 2s together and my question is how much wheat is there? You know would that be a nice pile here in the studio. Would have filled a building, would it cover the county to adapt the 2 meters. How much wheat are we talking about ? The answer is, it is roughly 400 times the 1993 worldwide harvest of wheat. Now that could be more wheat than humans have harvested in the entire history of the earth. You say, how would you get such a big number. It was simple we just started with 1 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 4th square, the 8 is larger than the total of 7 that were already there. When we put 32 grains on the 6th 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 would have used in all of the preceding growth. Now let us translate that into the energy crisis here as an ad.

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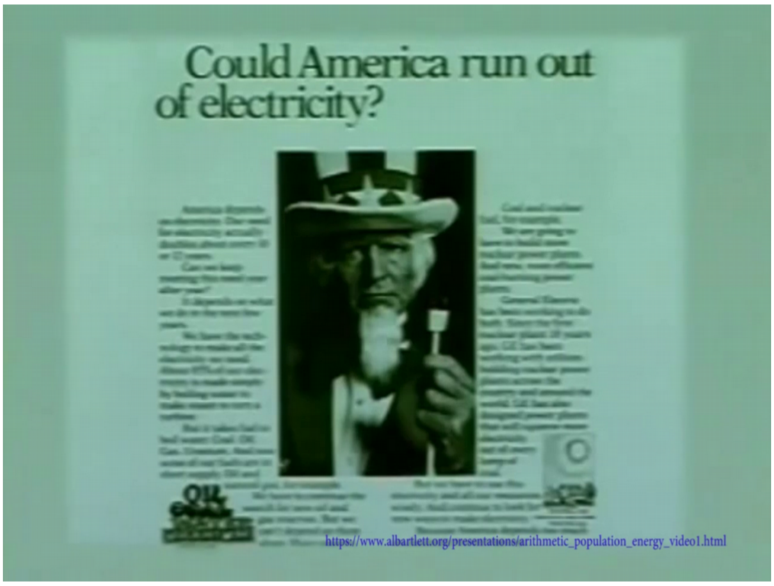

From the year 1975 and I would have asked the question, could America run out of electricity?

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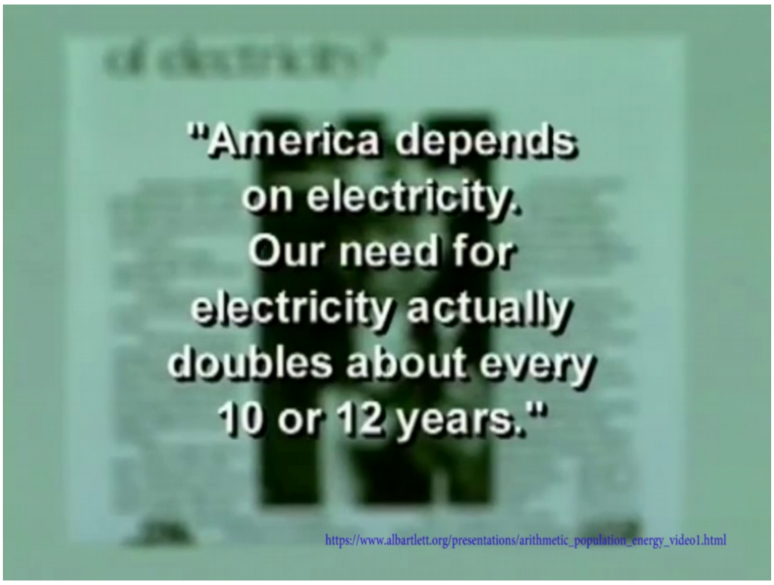

America depends on electricity. Our need for electricity actually doubles every 10 or 12 years. That is an accurate reflection of a very long history of steady growth of the electric industry in this country growth at a rate of around 7 percent 3 year which goes with doubling every 10 years.

Now with all that history of growth expected, the growth could just go on forever. Fortunately, it stopped not because anyone understood the arithmetic, it 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.

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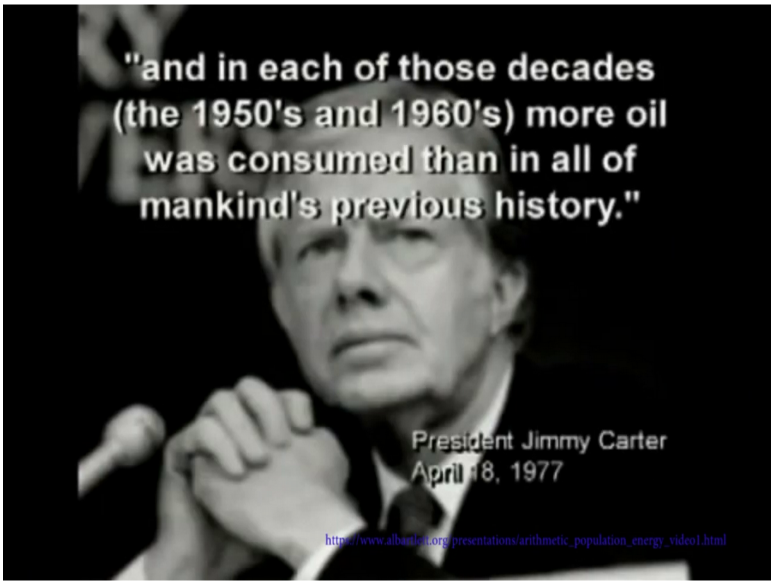

Well that is exactly what President Carter was referring to in his famous speech on energy. One of his statements was this. He said and in each of those decades more oil was consumed than in all of mankind's previous history. Now by itself that is a stunning statement. Now you can understand it. The 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 70 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.

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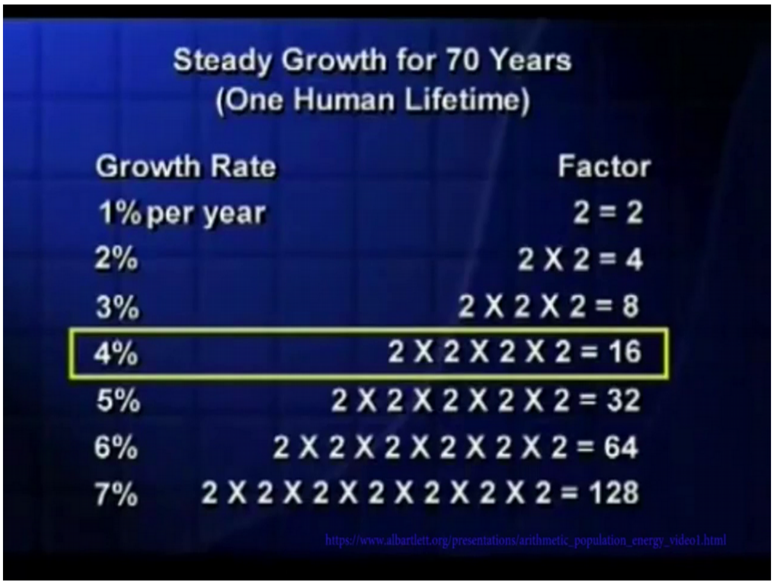

For example, 4 percent per year you find the factor by multiplying 4 2s together, it is a factor of 16. Now, a few years ago one of the newspapers here in Boulder quizzed the nine members of the Boulder City Council. And I asked them what rate of growth of Boulder's population do you think it would be good to have in the coming years ? Now, the 9 members of the Boulder City Council. So, 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 0 population growth right now. The number of Americans is increasing by more than 300 million people every year.

No member of the city council said Boulder's should grow less rapidly than the United States is growing. Now, the highest answer any council member gave was 5 percent per year. Well you know I felt compelled. I had to write him a letter as he did you know the 5 percent growth for just 70? I can remember when 70 years used to seem like an, a long time. It does not seem so long.

Now, well that means, Boulder's 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.

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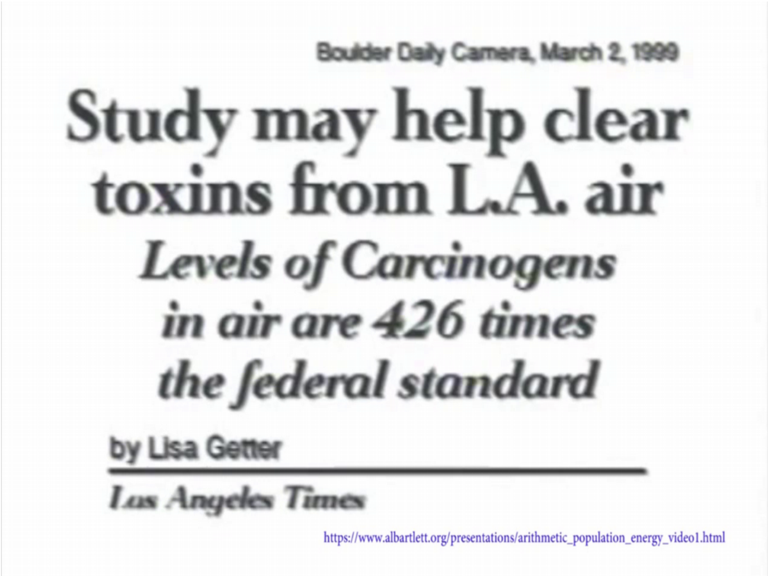

Here is an interesting headline from Los Angeles.

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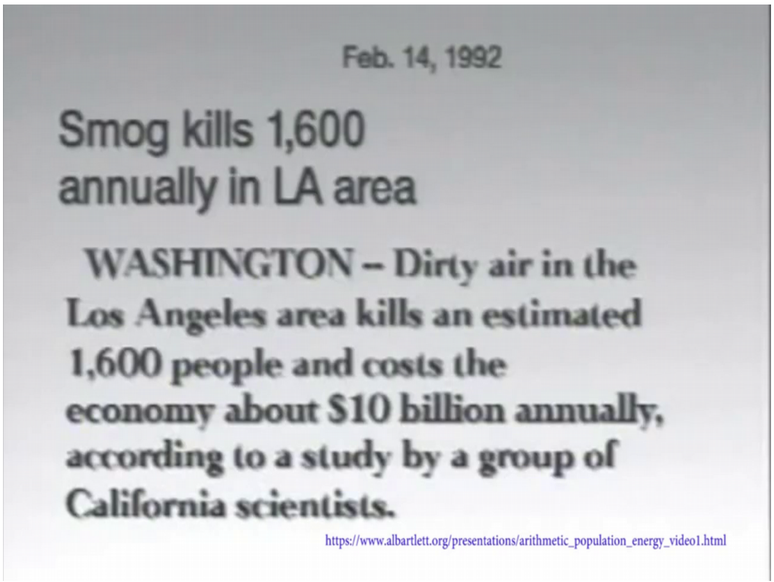

That headline probably has something to do with this headline. So, well how are we doing in Colorado?

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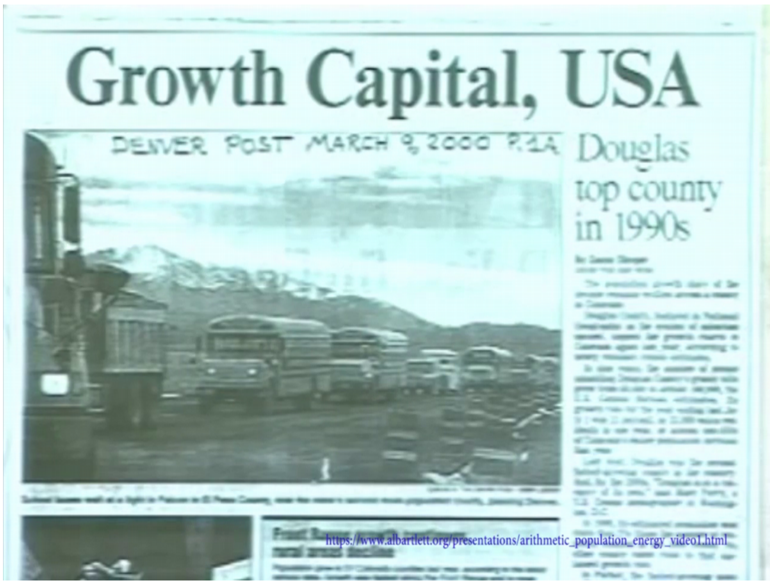

The Denver post tells us that where the growth capital of the USA and proud of it.

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The Rocky Mountain news tells us to expect another 1000000 people in the front range in the next 20 years.

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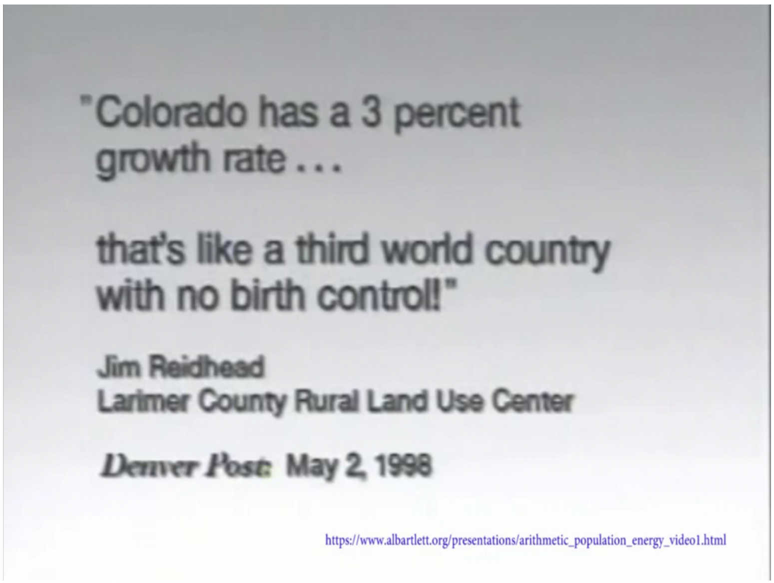

But in the post there was an interesting story. Someone was quoted as saying, Colorado has a 3 percent growth rate, that is like a third world country with no birth control. We send foreign aid, family planning assistance to countries that have smaller population growth rates than Colorado has. Well, 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.

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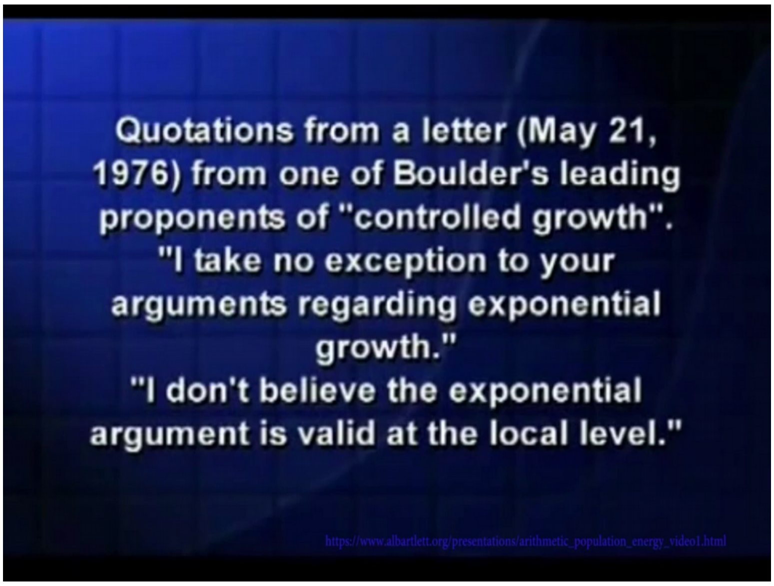

Now, controlled growth just means growth. This man writes, I take no exception to your arguments regarding exponential growth. I do not believe the exponential argument is valid at the local level.

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.

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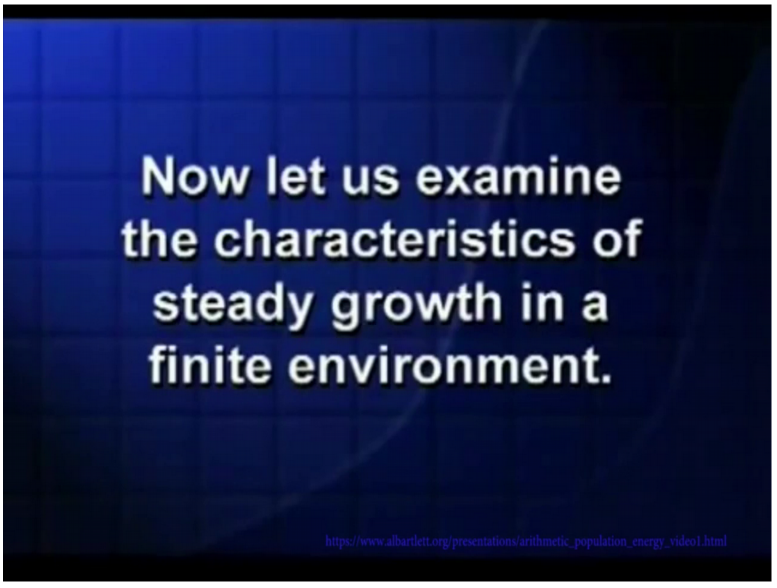

Let us look now at what happens when we have this kind of steady growth in a finite environment. Bacteria grow by doubling and 1 bacterium divides to become 2. The 2 divide to become 4. The 4 become 8, 16 and so on. Suppose we had bacteria that doubled in number this way every minute.

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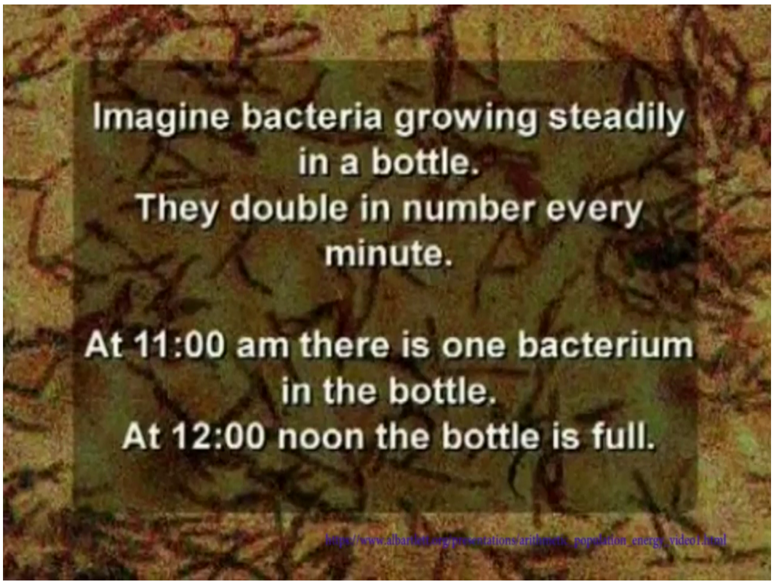

Suppose we put one of these bacteria in an empty bottle at 11 in the morning and then observed that the bottle is full at 12 noon.

Now, there is our case of just ordinary steady growth it has a doubling time of 1 minute. It is in the finite environment of 1 bottle. I want to ask you 3 questions.

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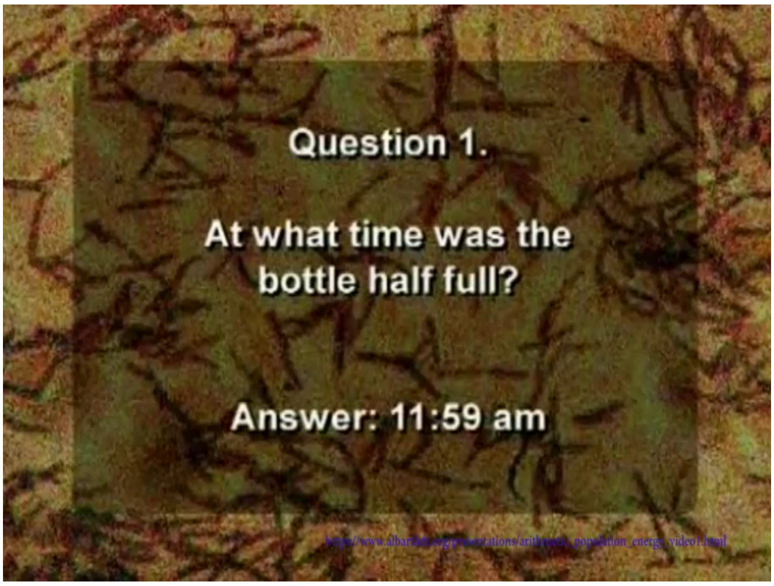

Number 1, at what time was the bottle half full? Well, would you believe 11:59, 1 minute before 12 because they double the number every minute.

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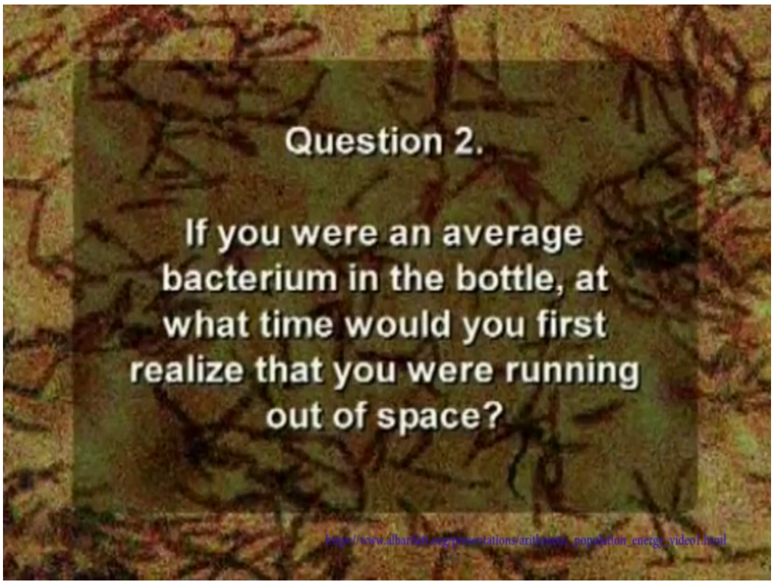

And the second question. If you were an average bacterium in that bottle, at what time would you first realize that you were running out of space?

Now think about this. This kind of steady growth is the centre piece of the national economy and of the entire global economy. Think about it. Well, let us just look at the last minutes in the bottle. At 12 noon it is full, 1 minute before it is half full.

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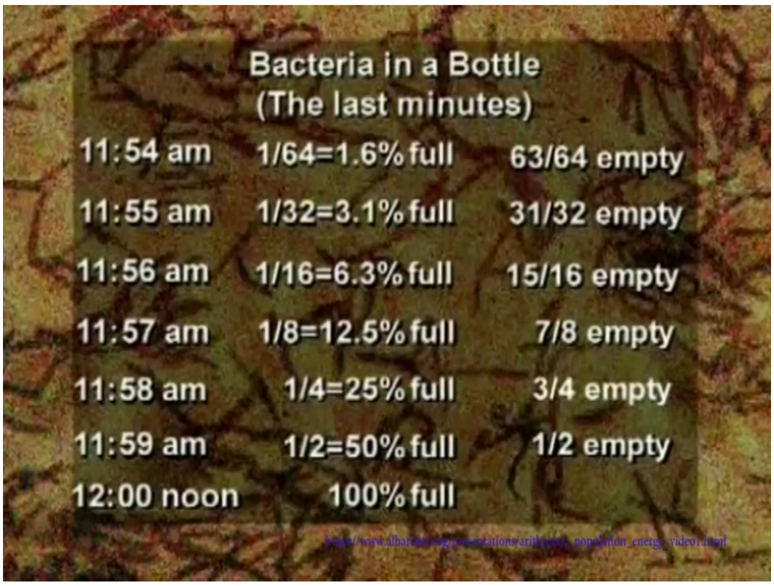

2 minutes before it is a quarter full, that one-eighth and ten-sixteenth. Let me ask you at 5 minutes before 12, when the bottle is only 3 percent full and is 97 percent open space just yearning for development. How many of you would realize there was a problem?

Now in the ongoing controversy over growth, in Boulder someone wrote to the newspaper 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.

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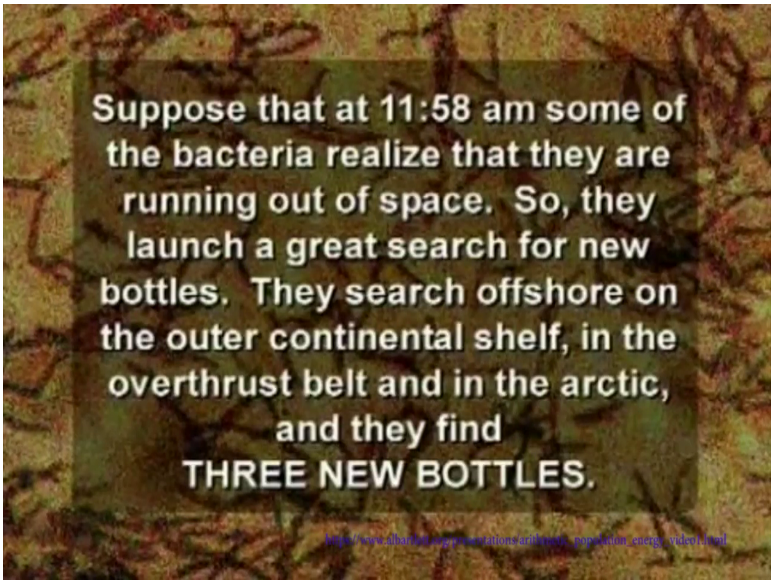

Well suppose that at 2 minutes before 12, some of the bacteria realized that they are running out of space. So, they launch a great search for new bottles and they search offshore, on the outer continental shelf and the Overthrust Belt and in the Arctic, and they find 3 new bottles. Now, that is a colossal discovery. That discovery is 3 times the amount of resource they ever knew about before. They now have 4 bottles.

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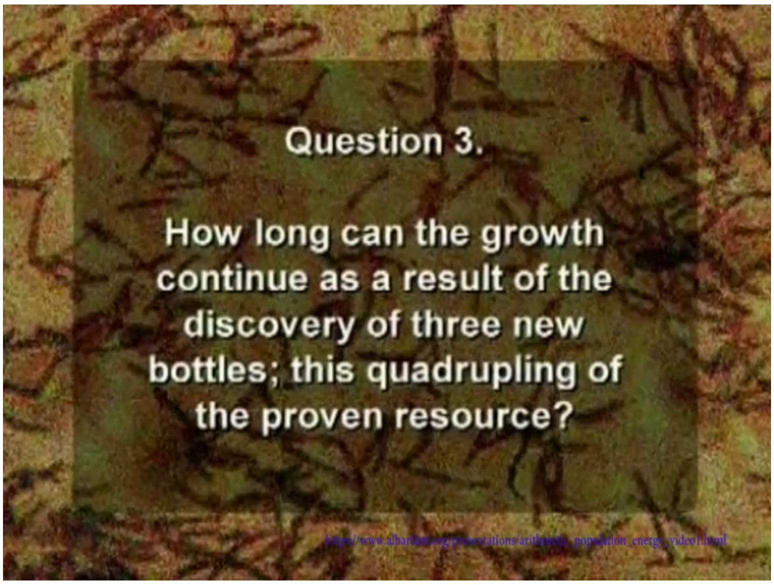

Before the discovery, there was only 1. Now surely this will give them a sustainable society, will not it? Would you know what the third question is? How long can the growth continue as a result of this magnificent discovery?

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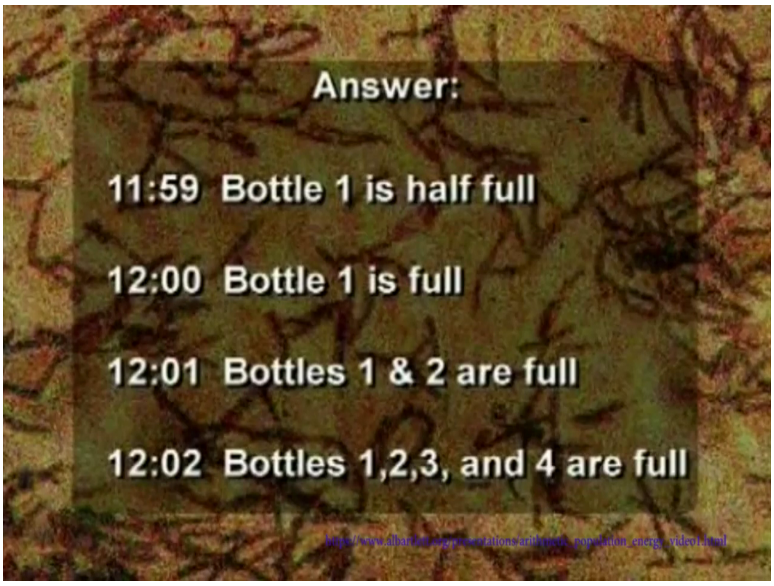

Well, let us look at the score, 12 noon 1 bottle filled there are 3 to go. 12:01 2 bottles are filled there 2 to go. And at 12:02 all 4 are filled and that is the end of the line. Now, you do not need any more arithmetic than this to evaluate the absolutely contradictory statements we have all heard 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.

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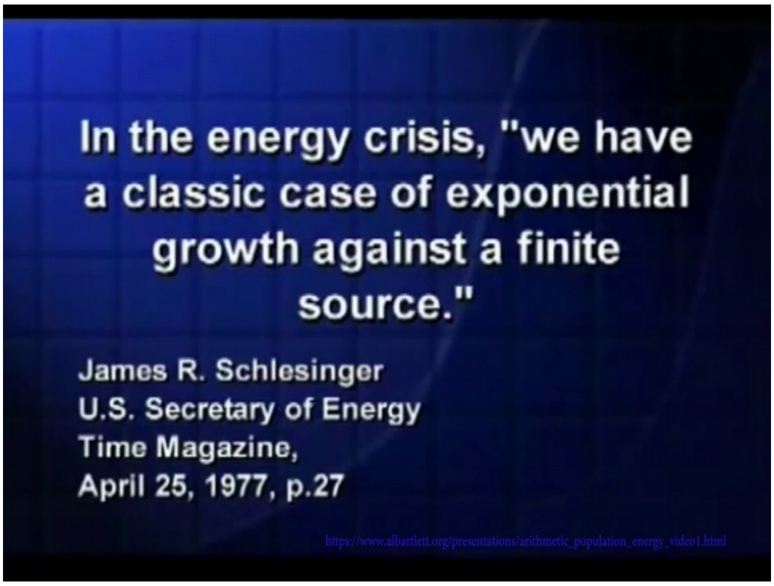

Well, some years ago in Washington, our energy secretary observed that in the energy crisis, we have a classic case of exponential growth against a finite source. So, let us look at some of these finite sources from the work of the late Dr. M. King Hubbert.

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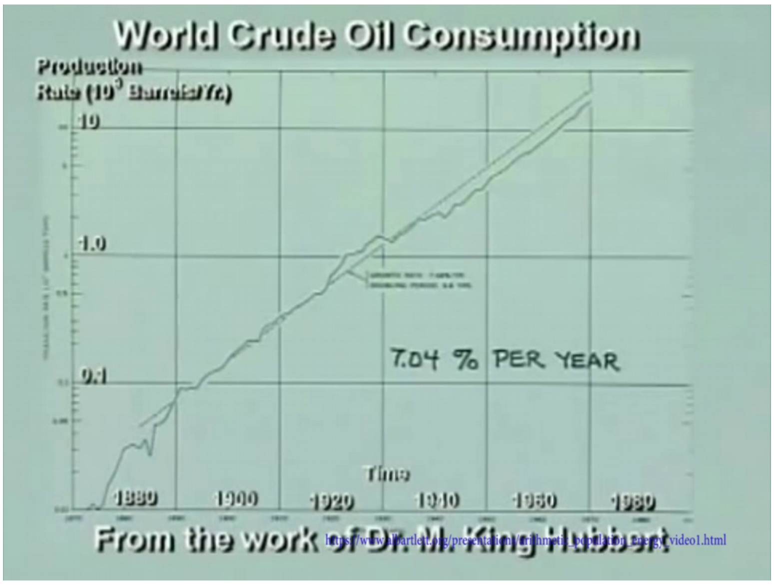

We have here his semi-logarithmic plot of world oil production. The line has been approximately straight for over a 100 years, clear up here to the year 1970. Average growth rate, very close to 7 percent per year. So, it is logical to ask. Well, how much longer could that 7 percent continue?

Well, that is answered by the numbers in this table.

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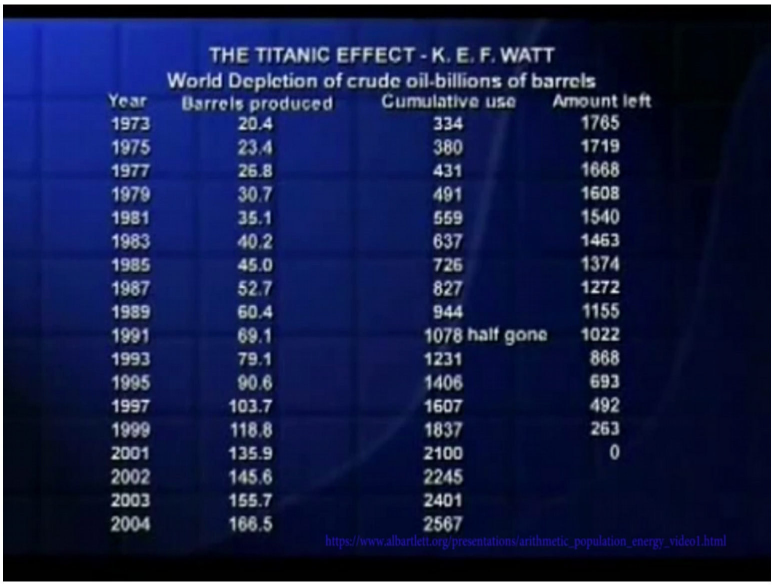

THE TITANIC EFFECT - K. E. F. WATT

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	

https://www.albartlett.org/presentations/arithmetic_population_energy_video1.html

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 is 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?

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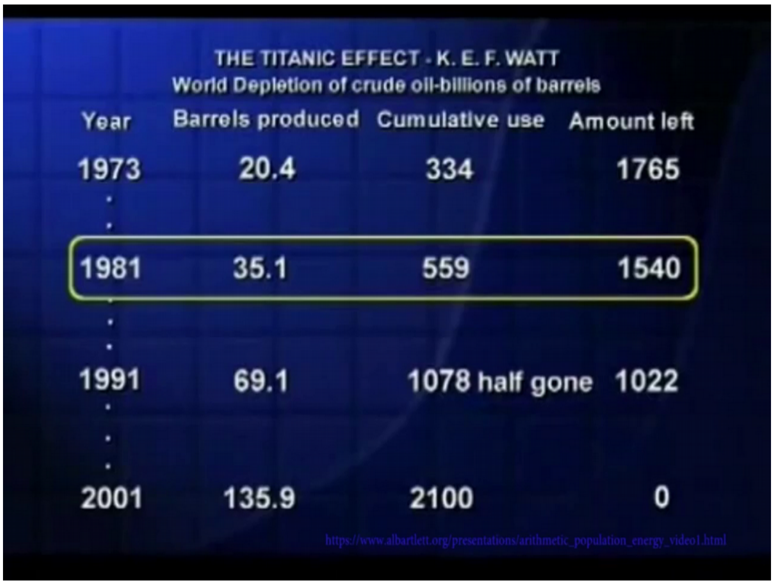

Let us go back to the year 1981. By 1981, on the 7 percent curve, the total usage in all of history would add up to 500 billion barrels. The remaining reserves 1500 billion. The reserves at that point are 3 times the total of all that have been used in all of history that is an enormous reserve.

But what time is it when the remaining reserve is 3 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 1000 billion barrels that would be a 1000 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 it is 1 minute before 12. So, we go one more decade to the turn of the century that is like right now. That is one 7 percent would finish using up the oil reserves of the earth.

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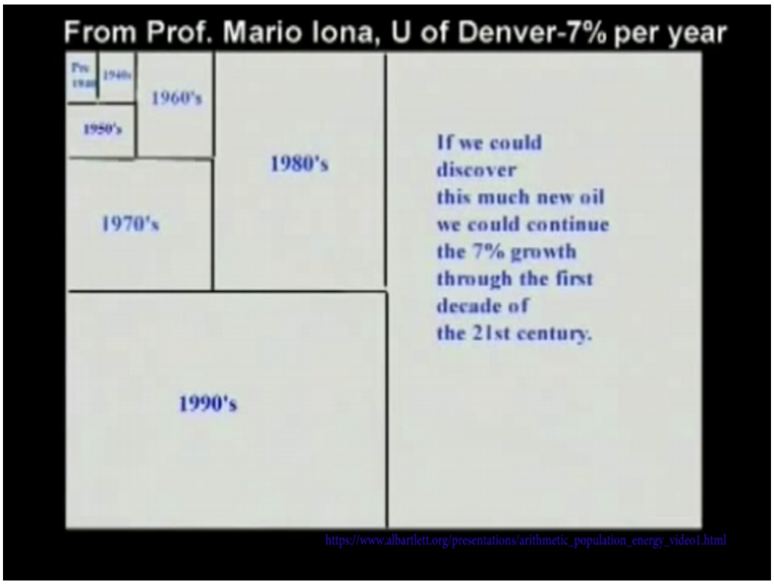

Now, let us look at this in a very nice graphical way. Suppose the area of this tiny rectangle represents all the oil we used on this earth before 1940. Then in the decade of the 40s, we use this much that is equal to the total of all that have been used in all of history. In the decade of the 50s, we use this much that is equal to the total of all that have been used in all of history. In the decade of the 60s, 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 70s, 80s and 90s. 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, it 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 continued 10 more years.

Well ask yourself, what do you think is the chance? That oil discovered after the close of our class today would 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.

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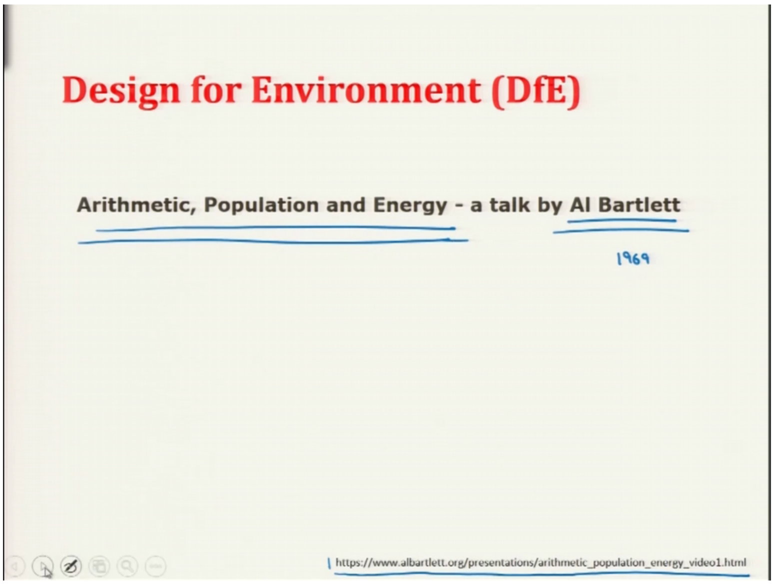

This was Professor Al Bartlett, who was a pioneer professor. He died in 2013. He was an alma mater of Colgate's University in Harvard University. And he worked in University of Colorado Boulder, where he developed the research in these lines.

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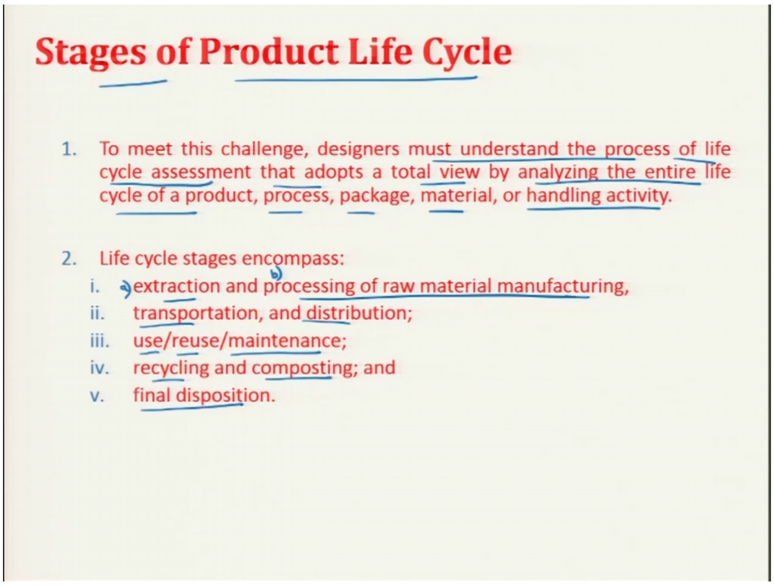

Now, we have a little feel that what is the impact of not considering the environmental issues these days. So, let us try to come back to the stages of Product Life Cycle. This we have discussed before, the procedure of product life cycle that professor (Refer Time: 25:56).

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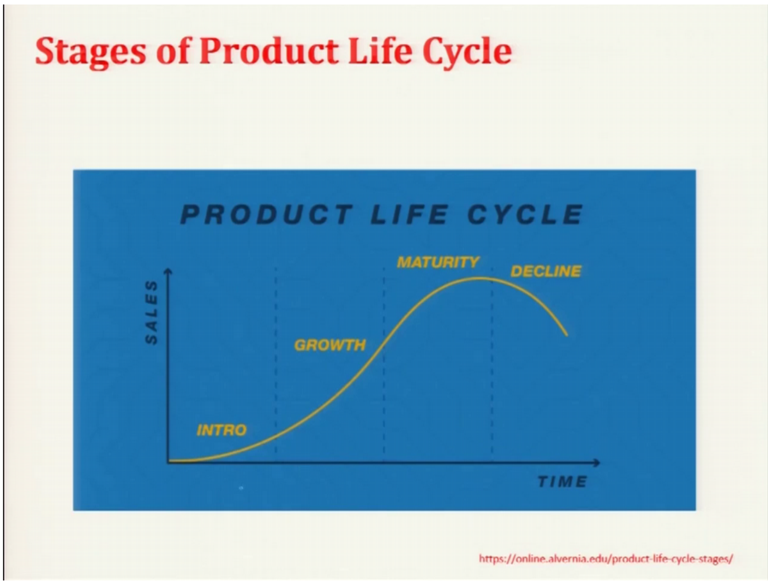

We will have discuss the Product Life Cycle goes like this. This sales are here, the time goes like this, the product is introduced to market then growth maturity decline. This is something I am not going to consider in this lecture. The product life cycle that I am telling is the other viewpoint from the extraction of the ore to the following use of the product and then disposal of the product. So, if you remember we had discussions on before use, during use and after use. I'm talking about that Product Life Cycle in this lecture, not this one, not this one.

So, in this product life cycle, to meet the challenge of the design for environment, these designer must understand the process of Life Cycle Assessment LCA that adopt a total view by analysing the entire life cycle of a product, process, package material or handling activity. So, life cycles stages encompass these 6 stages. Number 1 is extraction and processing of raw material, here processing means manufacturing also ok. So, raw material extraction is number 1. If I have need to put in a 2 factors here, factor a and factor b. Part one, then transportation and distribution then use reuse and maintenance then recycling and composting then final dispositions.

Now, what is extraction? The product that we use for instance, you use a car, the car is having multiple materials in it. It has aluminium, it composites, plastics, polymers, rubber, various conserved materials are there. Those are extracted from some source before, it is extraction of ore. Please be mindful, I am talking about the extraction of ore.

That means, a very initiation of the product from the ground. The ore is extracted then it is treated to make it usable then the, the methods are extracted from that or the material are extracted.

Then comes processing; processing is, that is manufacturing, that we are all talking about this part b is processing, but when we are talking about Product Life Cycle after processing also what happens. We have to package the product, packaging then for instance you buy a car. You go to the showroom to select a car, those are transported there from the manufacturing unit, that transportation ok. Then distribution to different units, then is used; used by the 1st owner, used by the 2nd owner, reused, then maintenance.

The average maintenance cost and inputs those are coming, there are inputs in maintenance also those are coming. So, that maintenance then when we try to completely dispose the car. So, when the car has worked for its operating period, then we try to send the car to the this maintenance section. Now, what does this maintenance section do? It do recycling.

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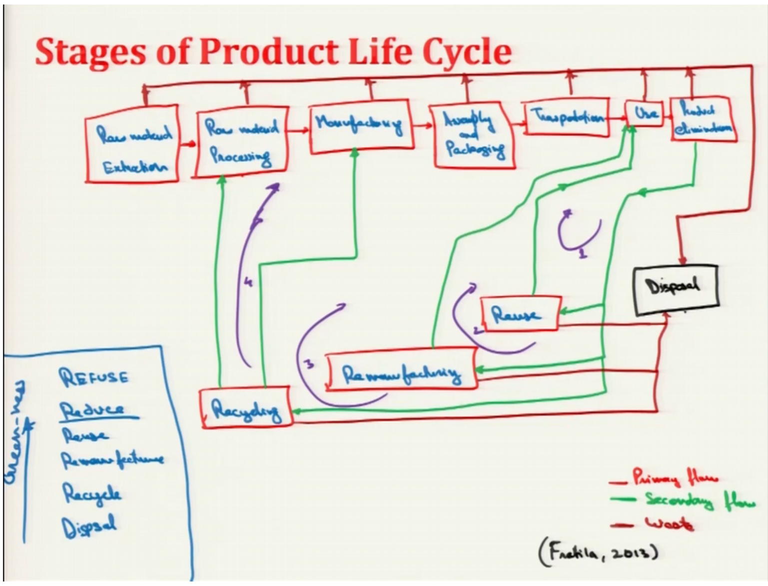

Then composting, then final disposal, these things happen. If I put these stages here, 1st is raw material extraction ok, 2nd is the raw material processing, 3rd is manufacturing, then comes assembly and packaging. After this transportation right, after use what happens one finally, eliminates the product. I would say product elimination. These are the major stages. Raw material, extraction, raw material processing then is manufacturing, then assembly, then transportation, then use and product elimination. So, it goes in this direction.

I would like to show you how reuse, recycle, remanufacturing work and from where it can be connected again. For what can be reused here at material processing stage. What can be used at material extraction stage and what can be used reused at manufacturing stage itself. So, these things let us discuss. So, what happens? These are the stages from where the disposal come here. This is actually disposal, which is the final resort if nothing can be done. But before disposal what we can do? If you let me put 3 words here, we can recycle, recycling, remanufacturing and reuse right?

What happens reuse is one when uses the product, one person eliminates the product and other person can reuse this product like I took the example of the car. This again becomes a use for the new person. So, this is one cycle, it is moving in this direction. So, it is moving in this clockwise direction. It is coming from here and going here, this is reuse. So, the first resort that design for environment discuss is reuse; if not reusable then we can remanufacture, that is maintenance and repair all those things. So, even this product elimination can come here remanufacturing. So, where does this remanufacturing go, after remanufacturing the product can be again reused.

This is actually the flow, the secondary flow of the product. In red colour I am showing the primary flow. This is primary flow, I would put here, this is secondary flow. And in the red colour we have primary flow here, these arrows ok. Now, the secondary flow can further come to the recycling stage from product elimination. It can even come to recycling stage here. Components to the recycler, for instance some of the components aluminium can be again melted and casted into new forms.

In remanufacturing what happens? Remanufacturing is overhauling of the engine, the denting and painting and all those things those comes in remanufacturing to make the product reusable again that comes here. If that is a possible then recycling can happen. Recycling is aluminium, plastics all those components are taken about and they can be used for some other purposes. So, that is recycling that. So, that goes here to the manufacturing process again right? This is recycling.

Now, recycling can also go, some of the parts can also go to raw material reprocessing. Like I said, aluminium can be casted and can be rebuilt or reshaped into different form. The different grades of aluminium, the body aluminium is different, the aluminium that is used for the pistons that is different. Different grades of duralumin, all those materials are there, so, this is the secondary flow.

In between we have here is waste. Waste comes here like this. I will put maroon colour for waste. Waste is that comes to disposal waste comes from all the stages from all these stages waste could come. From raw material processing there comes waste here ok.

From this direction, this direction, this direction, when we are reusing or remanufacturing here also the waste comes here in this direction, in this direction waste comes and in this direction waste comes. So, this is the final disposal I will put it in a black box, this is the disposal that should be provided. As far as possible; however, any product has a operating life and it has to finally, disposed of here only trying to enhance this life as far as possible.

The final name has to be actually Waste-free Manufacturing or Waste-free Manufacturing Processes and Resource Recovery. This is an illustration that is adapted from the work done by Fratila in 2013. You can read the complete paper if you like. So, the goal of reuse, recycling, remanufacturing, that is emerged with the innovative engine materials, manufacturing processes and systems which are aiming to provide multiple lifecycle products. So, we are trying to having have the multiple life cycles. If we try to put it here, this is 1 circle, this is 2nd circle, this is 3rd circle, this is again 4th circle that is going from this direction again for raw material, so, this is 1, 2, 3, 4.

So, we are trying to produce multiple lifecycle than just 1. 1 is just purchasing the product like extraction of ore then manufacturing, transportation etcetera etcetera using disposal that is all. No, this is only one life cycle, let us try to reuse, remanufacture, recycle and try to have multiple life cycles here. So, this is the ultimate aim of this discussion. The need of ecological efficiency and the environmental concerns are often associated with the production of minimum waste. Minimum waste means minimum toxic omissions; toxic omissions into air, soil, water any of these emissions are to be avoided and minimum consumption of energy. So, these all are to be aimed at.

So, what we can do in reuse? So, reuse is nothing, but using the product again and again and it is the change of the owner or we reuse product in some different way. Like the paper that we are printing the one side of the paper is plain and if those paper are not usable the second side can be reused. It can be reused and then that can be used to recycle finally, if the both sides are printed and then got they are not required any more. So, that is that reuse in some different way or reusing of towels or cotton clothes to mop the floor. So, this is all the examples of reusing.

So, recycle in traditional sense is where you might spent your oil for fuels blending and it is recycled as a fuel. Or maybe you send your fluorescent light electronics into facility where it is dismantled and the parts are recycle separately. Then however, other wastes that are not hazardous wastes that also have the ability to be recycled. These are a few recycle examples. Then remanufacture is nothing that is just maintaining or working on the product to bring it in the usable form.

The finally, product has to be disposed here disposal, before disposal we can recycle and before this we can remanufacture. Before this we can reuse and also before this we can reduce. Reducing the production and this is how the sustainability or greenness that rises in the selection and also one can even refuse. That is refusing is limiting your needs, but that is not a thing people are demanding more and more products with the more and more facilities. So, these things are coming to play. So, this is how greenness goes like this. These are the typical stages of product life cycle and the product life cycle of bits.

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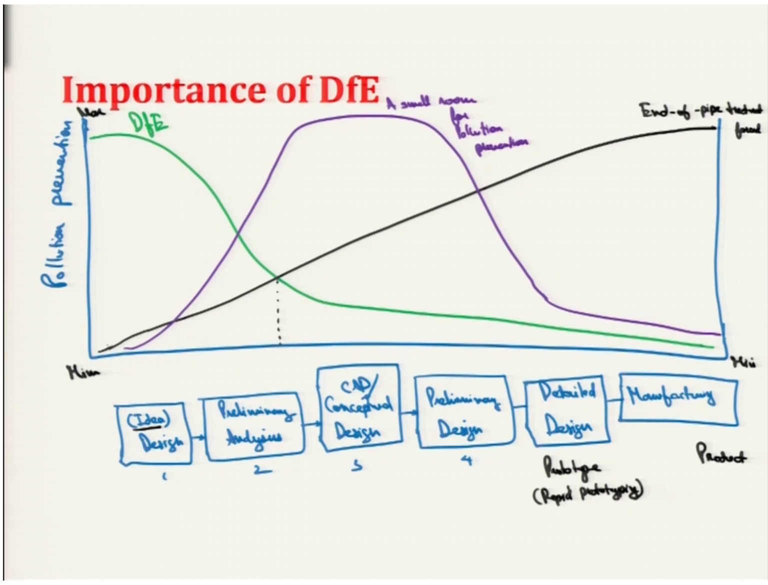

So, what is the importance of design for environment when we talk about design for environment so, if I talk about the manufacturing and all, how does that happen? We have the CAD model before or we have design here ok. After design in manufacturing we have the, a preliminary analysis, right.

Then we have the conceptual design, after conceptual design we have preliminary design. After preliminary design passed, we have detailed design and then we have final manufacturing, right?

So, this is the flow of the manufacturing. We will make a design or the CAD would actually go here. This is just the idea ok, to correct myself. So, idea is there the preliminary analysis is there whether the idea is possible or feasible or not. Then we go for CAD or conceptual design. What is the conceptual design? Then we make the preliminary design. This is just the initial CAD. The overall concept of the model in this stage, see this is 1, 2, 3, in stage 4 we have the preliminary design and we then try to see what are the various changes required. Then we make detailed design which had all the blue prints etcetera, then we go for manufacturing.

So, where essentially the design for manufacturing has to work like value engineering as we discussed. It has to start from very beginning. So, this is pollution prevention. Pollution prevention and pollution prevention is maximum if we conduct DfE here and it is minimum if we conduct DfE here. So, design for environment is considering the environmental impacts in the design stage itself. So, this is the line for or I would put a green line here. This is DfE and if we do not conduct DfE the other way is end of pipe treatment that is this in this direction ok. This is end of pipe treatment.

In between, in the previous session we discussed in that in value engineering this is the concluding point, but in between also it can be something like this, this is something like this. So, this is actually a small room for pollution prevention right. In green colour we have DfE and in black colour we have end of pipe treatment. End of pipe treatment that is manufacturing has happened and now we are doing it end of pipe or end of pipe treatment. This is forced here ok. That has to be done because the design is not good we have to work to the following environment.

So, the pollution rises in this direction. So, this is minimum, this is maximum, this is minimum and this is maximum here in this direction. Here we have idea, preliminary analysis, CAD, conceptual design, preliminary design and final manufacturing as we get here. Actually here we get the final product. And in the preliminary design or in the detailed design we can also have a prototype. These days this is known as rapid prototyping.

So, this is importance of DfE. With this I would like to have a break here and we will continue the design for environment in the next lecture. Where I will discuss the importance of DfE for the few lines on this would be discussed. Then we will see what is what are the sources of waste, then will go to our life cycle assessment.

Thank you.