Ground Improvement
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Module No. # 09
Lecture No. # 38
Sustainable Development and Energy Geotechnology

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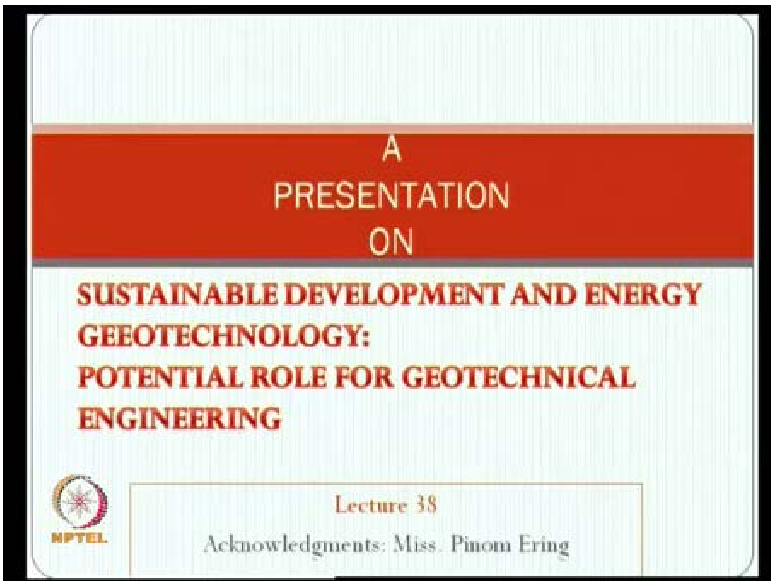

This area has a lot to do with sustainability issues that are prevailing in the area of (( )) nowadays. For the next three lectures, I would be addressing the topic of sustainability and sustainability development, which really has a big role in the geotechnical engineering. In this lecture, I would like to acknowledge the contribution of my student Miss. Pinom Ering and today, the presentation would be on sustainable development and energy geotechnology, potential role for Geotechnical Engineering. As you all aware, what is happening is that people are looking at the critical issues like economy and we need to have the society and environment. The interaction of the three pyramids the so called economy, society and environment have, they are all related. For the development of the quality of life of the society, you need to have a good environment and also the solutions have to be economical to that extent that, they should also not damage environment that we have. So, these three pillars of on the pyramid, this structure has something common like society needs good environment and also good environmental solutions but all the three, society, environment and economy, they need sustainable solutions.

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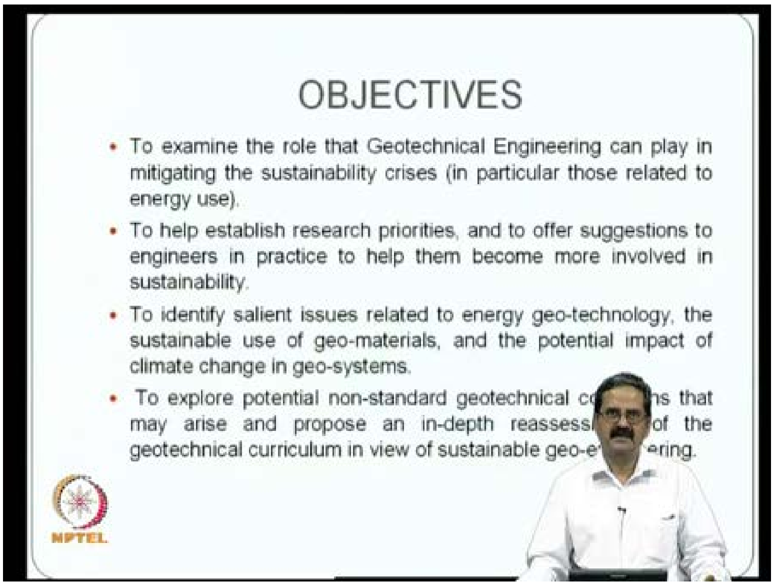

What it means is that, the sustainability is something that we need to define in this context that, we need to use a materials, natural materials that are available today, without affecting the needs of the future generations in a way that does not affect the environment, that does not affect the economy and also creates to general well-being. In this context, the role of geotechnical engineering is very significant. I must say that not just apart from environment, it is also more about energy reuse, energy use as well. I would like to just present some ideas on this today and also understand or establish a research priorities and offer suggestions in, who are practicing to get more involvement in the area of sustainability.

We also talk about salient issues related to energy geotechnology and the sustainable use of geo materials and the potential impact of the climate change in geo systems. We would like to see also, explore, certain non-standard geotechnical conditions that may arise and propose in depth reassessment of the geotechnical curriculum, in view of the sustainable geo engineering. What we studied so far, in the ground improvement areas is that, for example, if there is a civil engineering structure, earlier people were going for pile foundations. Of course, even now that is a order of the day but then, if they can be improved with, say for example, stone columns, a simple example. That can, that is a big difference like say for example, the consumption of the carbon in the case of cement and steel is much higher and whereas, you are trying to use some sort of a stone or some other aggregated materials, in the case of soft soil, when you want to increase the bearing capacity of soft soil.

What I mean to say is that, if you're trying to improve the bearing capacity of the soft soil, one solution is that, you try to use some sort of columnar structures, where the soft soil you have, say for example, 10 kpa of shear strength and you would like to improve the bearing capacity and reduce a settlements. Instead of the going for pile foundations, the stone columns is one liable option or geosynthetics is another option or geo self-foundations depending on many varieties of, you can have varieties of solutions. But at the same time you need to understand, what is a impact or what are the impact in terms of sustainability, that you are trying to contribute. We will discuss some of these things, in this class today.

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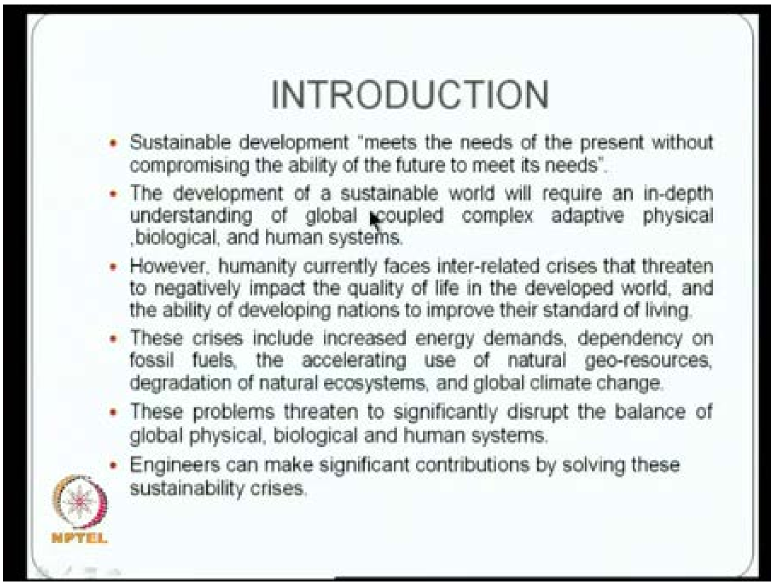

And as I just mentioned a sustainable development means you are trying to meet the needs of the present without compromising on the ability of the future generations to meet its needs. And the development of a sustainable world will need a very deep understanding of the global processes that are complex. There many of them, physical, biological and human systems. And nowadays, on the current scenario is that, many of these factors are inter related and they negatively impact the quality of the life. Whether in the developed world or developing world the things are happening. Because you are trying to make efforts in the developed world and also in the developing world and in the developed world, already there is lot of consumption of the carbon and then, they are trying to understand what is a, how can you go on from now on. And in particularly, in the developing countries, there are lot of construction activities that are coming up. Is it possible to really look at, what is sustainability in this context? So, why this things have become necessary is that, you need to have increased energy demands, like energy requirements are too high nowadays and they depend, they depend on the fossil fuels.

So, there is an accelerated use of natural geo resources, degradation of natural ecosystems and global climate change. These problems threaten to significantly disrupt the balance of the global, physical, biological and human systems. For example, there is a raise in temperature, people are aware that twenty years back, it was not that bad, but now you see that, there is a temperature raise and you see that lot of hills are being destroyed to construct roads in many areas and definitely, the ecosystem that you have, in the form of hills cannot be destroyed, just for a certain construction in the civil engineering. You need to really see that, there is, you need to balance the requirements of our requirements and also see that they do not affect the way we live. So, you need to, all engineers need to understand and make significant contributions by solving the sustainability crisis. It is very important. And I would like to say that, the energy crisis, though I must say that, how is that a geotechnical engineering is related to energy. You see in a minute, that they have a significant role, particularly in terms of geo thermal energy and other issues.

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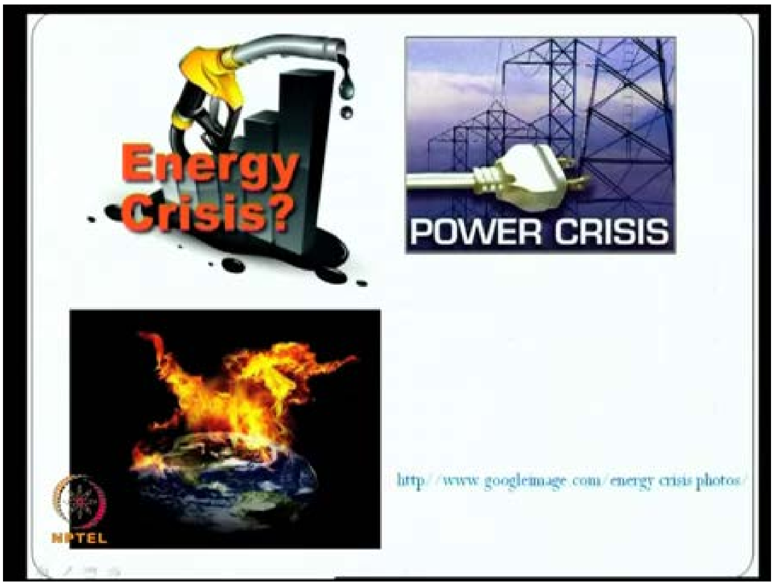

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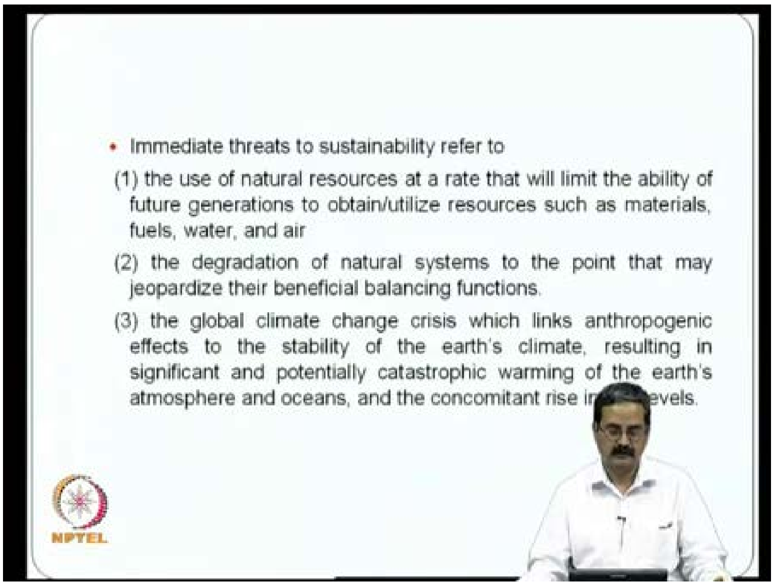

What are the immediate threats to sustainability? One is that the use of natural resources is at a rate that, will limit the ability of future generations to obtain or utilize resources such as fuels, water and air. So, we should not use the rate of, the rate of use of the natural resources should not be so fast, that it will affect the balance or the needs of the future generations. That is one thing, like you know material requirements. As I just mentioned, the aggregates, nowadays, the you normally the coarse specify good quality aggregates but then, you do not have good quality aggregates. Then, in this context why do not we use recycle aggregates or some materials that are stiffer and still solve the purpose of virgin aggregates.

Then, fuels you know, the thing is, now we are leaving on lot of petrol and other products but is it possible to have some alternate source of fuel, for heat generation? Of course, water has been another premier important. Water and air, we need all of that and we should see that this things are not affected. So, the degradation of the natural systems to a point that may jeopardize their beneficial balancing actions, say something that you know, what we know is that, if you the natural system should not be degraded. And then they, we have to have a balanced view of what we need and what you can use. That is one thing. And the global climate change crisis is nowadays, that we are all hearing that there is a temperature raise, there is a increase of carbon in the atmosphere which leads to increase in temperatures. They have links to anthropogenic effects and or the man-made activities. They have a big role in the stability of the earth's climate, resulting in significant and potentially catastrophic warming of the earth's atmosphere and oceans and the concomitant rise in the sea levels. This is a very significant point and in this context, how this geotechnical engineering can address is something that we need to see.

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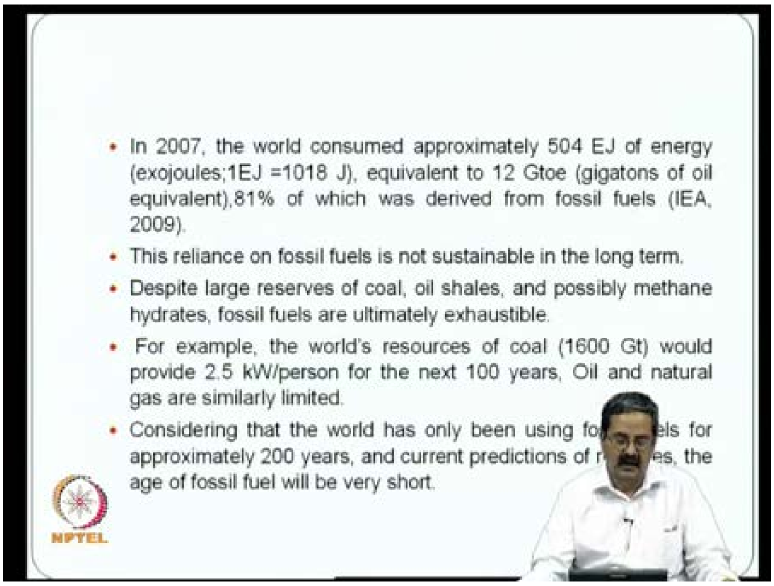

I will give an example. It is an estimate that in 2007, the world consumed approximately 504 exojoules of energy. 1 exojoule is 1018 joules and this is equal to 12 Giga tons of oil equivalent. So, this is something that you know in a 2007, 12 Giga tons of oil were used and out of which 81 percent of which was derived from fossil fuels, is something that is very alarming. This sort of reliance, like you know on the fossil fuels like, you are trying to get all the energy from the fossil fuels is not very sustainable. This is a very serious issue and though, we may have large reserves of coal, oil, shale's and possibly methane, hydrates, fossil fuels are ultimately exhaustible. So, everything is a finally, going to have a, everything is finite and the possibility is that you are going to exhaust some soon or later.

For example, the world's resource of the coal about, you have 1600 Giga tons would provide 2.5 kilo watt per person, for the next 100 years and of course, that definitely after 100 years, what is something that you need to understand. Similarly, oil and natural gas are limited. So, we need to understand that, you are trying to, if you are trying to use or work on fossil fuels as a source of our quality of life, definitely, they lead to lot of issues. The fact is that you have been using the fossil fuels, only in the recent times. It is not there, petrol use was not there about 100 years back. So much use was not there. Nowadays, you see that, it is the use has been so much, that the current predictions of reserves, the age of fossil fuel will be very short. So, this is something that we need to understand.

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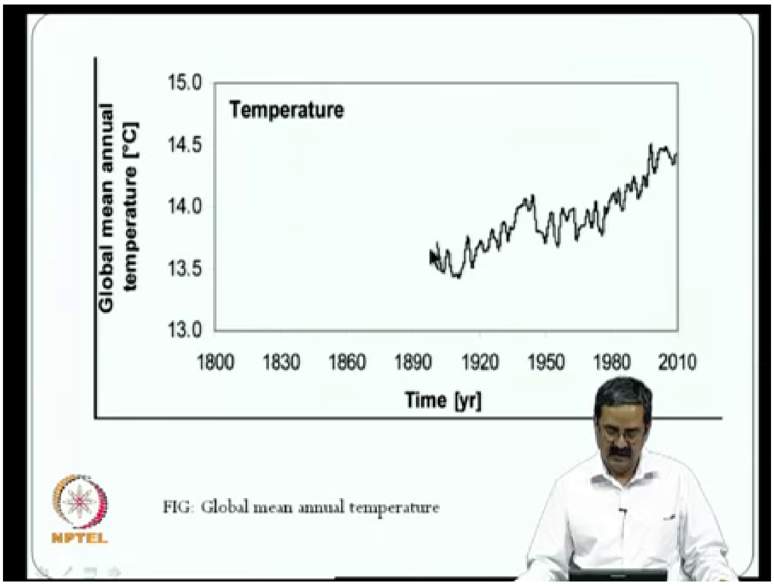

And for example, as I just mentioned, how is that global temperature going to get changed? You can see that in the year 1890, there was some temperature here. Say global mean annual temperature in centigrade, it is about 13.5 here. You can see in the year 2010, it became about, there is a one degree raise in temperatures. This is a big average, big change because though, this is a mean average, it means a lot for the ecosystems. So, this is a like say for example, the melting of the snows, melting of the, the changes in ocean levels, there are many issues that are connected with this and the climate change that we have been seeing today, is as a result of this point. And you look at carbon emissions that we see, like which are supposed to increase the, which are supposed to increase a temperature in the atmosphere. You can see that in the recent times, in the last two decades, the fossil fuel carbon emission in million tons of carbon, is about very high. It is about 8000, it is just increasing too much. So, your objective is to save this energy and also to contribute to some extent.

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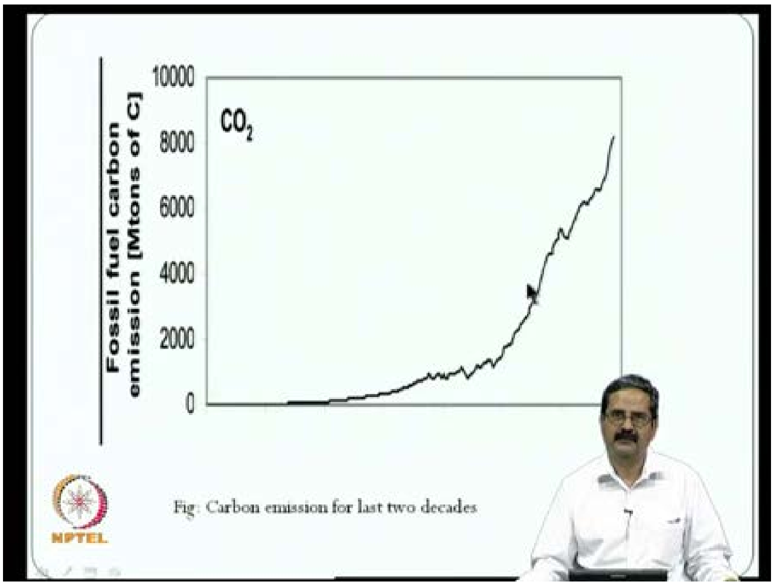

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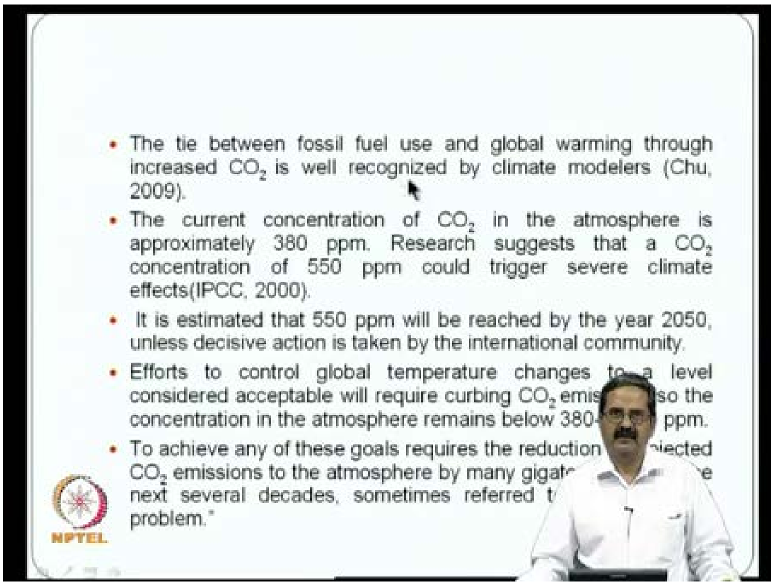

The relationship between the fossil fuel use and the global warming has been understood through the use of increased CO2, like we know that increased CO2 levels, will increase the temperature and this has been understood very well by climate modelers. And the current concentration of the CO2 in the atmosphere is about 380 ppm, parts per million. And research suggests that a concentration of 550 parts per million could trigger severe climate change. This is from IPCC 2000 report that, if you have a further increase in the carbon content or a concentration, the problem is that the climate changes are going to be much more drastic, if there is some increase. So, the objective would be now, that how do you stick on to this? And people estimate that the 550 ppm will be reached by the year 2050 and unless, you take a decisive action by all the communities, it is not easy to control this, concentration of the carbon. Efforts to control global temperature changes to a level considered acceptable will require curbing CO2 emissions.

So, the concentration in atmosphere remains below 380 to 450 ppm. It is a very, there is a now a specification which something is okay, like one can look at it and people need to work back, that what a particular nation should do or what a community should do or a what a international community, all of us should do together, to see that this limit of 380 to 400 or whatever you say, has been additive and we should never reach this limit of 550, because that leads to lot of climate change. So, to achieve these goals requires a reduction in the projected CO2 emissions to the atmosphere by many Giga tons over the next several decades and people always say that, this is a Giga ton problem.

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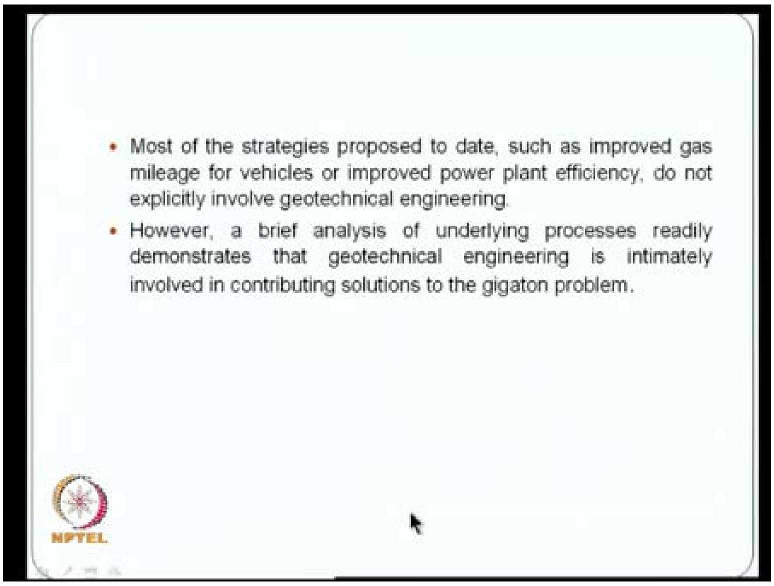

So, most of the strategies proposed to date, such as improved gas mileage for vehicles or improved power plant efficiency do not explicitly involve engineering, geotechnical engineering. You must have seen that, we have fuel efficient cars, but it does not mean anything. Say for example, you may have instead of ten kilometers per hour, you have an engine which has some 15 kilometers per hour but then, there is still a consumption of the gas, which is something very, a problem, problematic. Then, they are all, you know the thing is all disciplines, whether it is all branches of science and engineering, need to look at how do you reduce this carbon print on the atmosphere. And actually, geotechnical engineering is one big way. You know, if you have proper understanding in a geotechnical engineering principles and ground improvement principles, it has a very important role in the carbon credit, carbon print reduction. So, I will just introduce some principles here, the brief analysis of processes, the how and which geotechnical engineering can help and deduce this issue.

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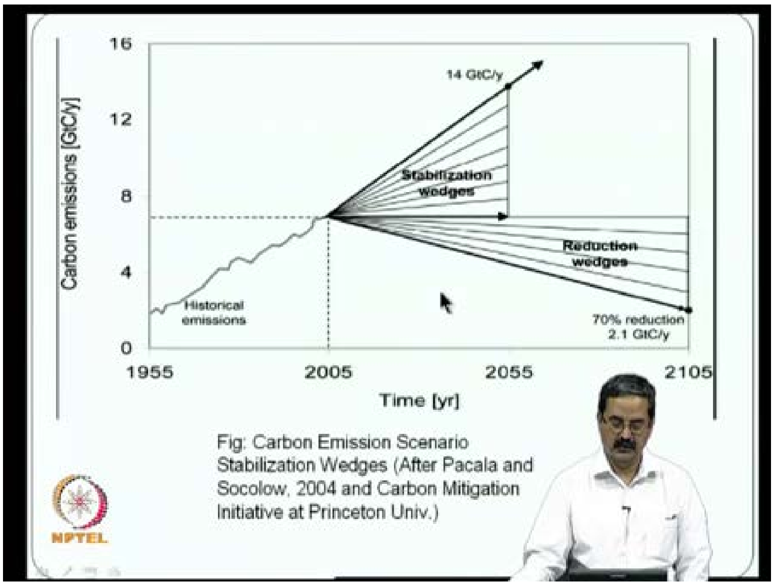

This is another figure which shows that, you have from 1955 to 2105, the time scale and you have carbon emissions in Giga tons per year. So, you know up to 2005, this is whatever has happened, has happened. But then, you continue at this rate, what happens? Definitely, you are going to be on a high scale. So then, objective is to, you know the rate has been at 14 Giga ton of carbon per year which just goes, it is going to significant. But then, you would like to reduce them in some way. So, you have reduced to some levels. So, for example, if you are aiming at a very good reduction, of 70 percent reduction and there is some way. You know, like you have different wedges drawn here, to see that you need to identify, what should be done. From here, you should be able to control, see this is a called stabilization wedges. You do not want to really go, follow this level, but then we would like to reduce by some levels like you know, come back, you reduce a slope of this line to this level or if you are trying to reduce this, this reduction wedges, you try to really come out with some strategy of stabilizing or reducing. This is a point here. So, you need to come out with various methods of coming out with this plans. So, that, the ultimate carbon emissions will not endanger the atmosphere.

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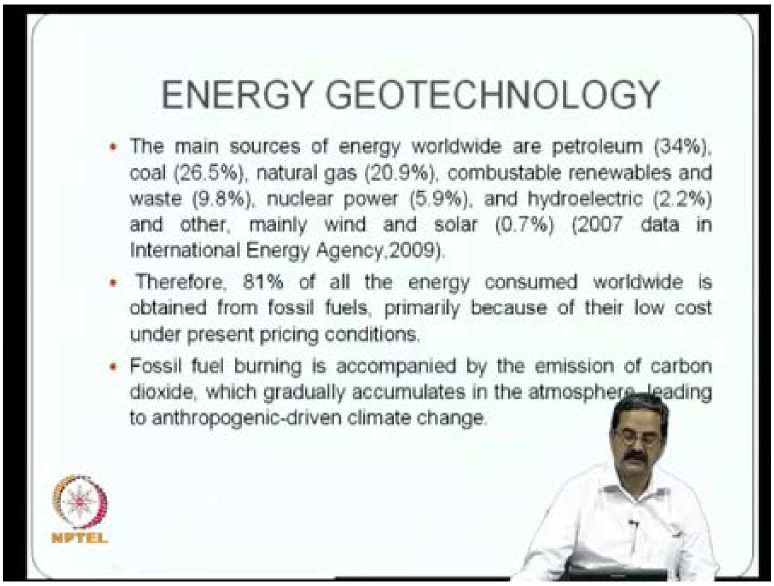

People have been working on this particular point, nowadays like I was in one conference in US about three months back on geotechnical engineering and how geotechnical can help apart from ground improvement energy. See, it has become a topic called energy geotechniques, where you have multiple ways of handling the ground engineering problems. Nowadays, the ground engineering has been not just limited to ground improvement. The concept is that, you have an all-encompassing attitude that helps the globe like you know, reduces the global warming and also provides energy and energy recovery, waste recycling. Suppose, there is a waste material that can be used in a road project, definitely, it leads to consumption of, reduction of carbon emissions.

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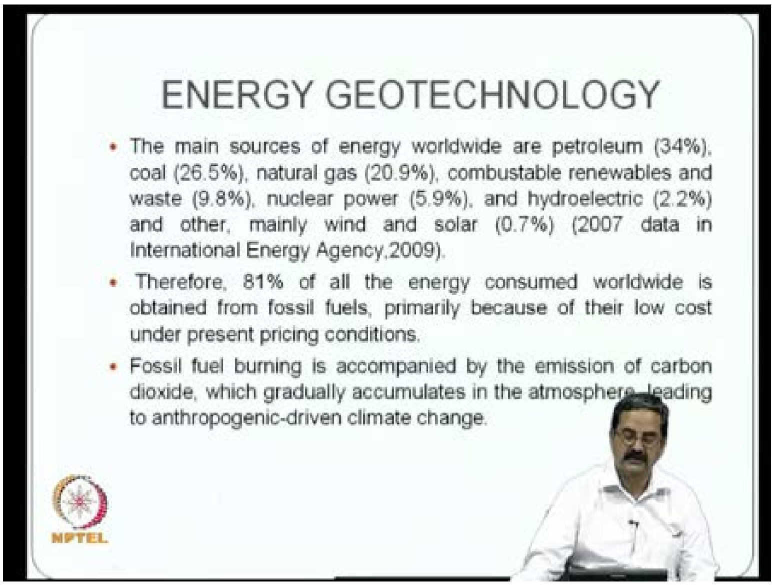

So, people have been talking about this and in this context, the coining of the term energy geotechnology as a part of the ground improvement is something that needs to be accepted. The main source of energy are petroleum and about say for example, 35 percent. We have coal 26.5 percent, natural gas about 21 percent, combustible renewables and waste about 9.8 percent, nuclear power 5.9 percent, hydroelectric 2.2 percent. The other, mainly wind and solar, of course, the efforts have been less in this and as per the 2007 data and of course, it varies, it is a general thing. But then, different countries have different numbers in this area and definitely, people have been you know, different countries have been placing energy the emphasis on say for example, nuclear power. They are trying to place emphasis on hydroelectric projects and also the wind and solar energy. And fact is that people have been trying to make all out efforts, to see that this concept of energy using geotechnical principles can be helpful. And as I said earlier, 81 percent of the energy is consumed worldwide is obtained from fossil fuels and primarily because of their low cost present under present conditions.

Why is that people trying to go for this fossil fuels? Because, now with the we are trying to remove the say for example, petroleum from some places because of the investments that are required and the cost that are involved, it has been low. But then, if you do an analysis, in terms of the climate change and its effects and all that, may be this is not acceptable at all. Say for example, the concept of fly cycle cause, like or the emissions reduction or emission increase because of using a particular technique over a long period of time, needs to be understood in terms of the life cycle cause. Even, in the life cycle cause for example, if somebody is working on how much is the life cycle cause after 20 years and may be that is a better alternative. Possibly, you must go for how much of carbon reduction footprint is there, after a say 10 years or 15 years that may be a better basis than trying to simply go by life cycle cause analysis, in terms of currency. So, what I want to say is that, the fuels which are having emitting lot of carbon dioxide, which gradually accumulates in the atmosphere, leads to anthropogenic driven climate change, needs to be avoided. This is what I would like to say.

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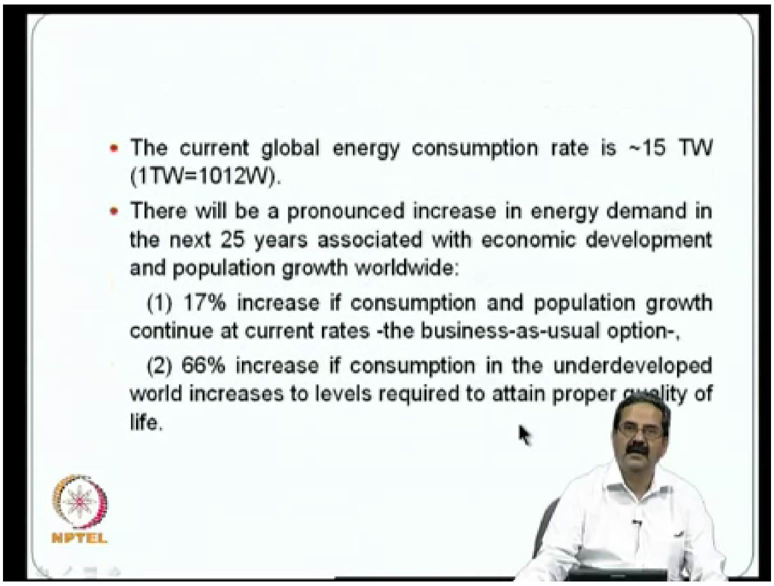

And the current global energy consumption rate is about 15 terawatts and there will be a pronounced increase in the energy demand in the next 25 years because everybody is looking for economic development. And there is also population growth. If you look at these two factors, you can say that 17 percent increase, if consumption and population growth continue at the current rates, the business as usual option. One way of looking at the problem is that, just do as it is and have the practices that you have. So, the 17 percent of the 17 percent increase in the consumption and then, population growth, the 17 percent increases in terms of the, for the energy requirement. You know, it is huge, 17 percent increase is huge. And the second thing is 66 percent increase, if consumption under developed countries in world increases to levels required to attain proper quality of life.

We know that, the quality of life in some countries is not good. And of course, the way the quality of life is defined is something that needs to be examined in a detail, in a context of what consequences it has, like 66 percent increase is a big increase and suppose, you want an under developed country, they want to have a, they do not have fuels and then, they would like to rely on fossil fuels. And burn their existing options, then, the problem is that the, you know it leads to a very significant effects on the, you know it is a big bearing on the energy demands as well as energy, the climate change as well.

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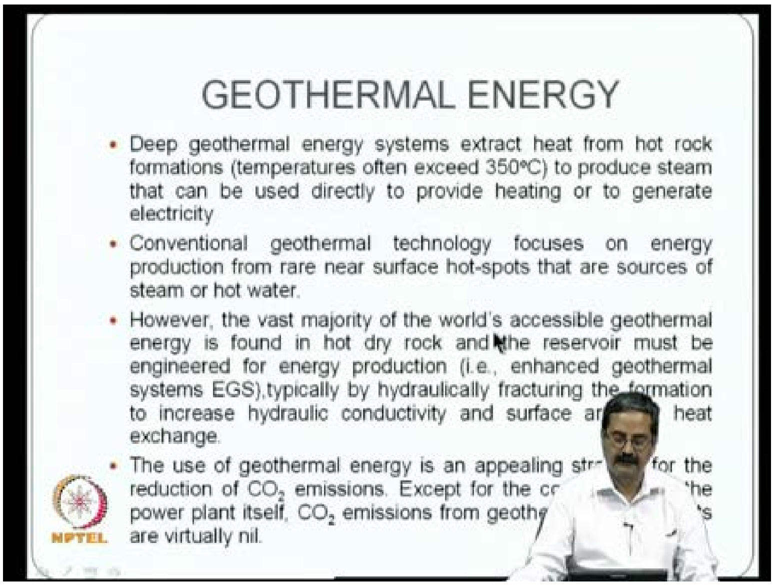

So, what people have been trying to do is that, people are looking at a geo thermal energy as a source of energy, which is nothing but people are you know, say for example, deep geothermal energy systems are there. They extract heat from hot rock formations. You have hot rock formations under this earth, where the temperature is about 350 degrees, to produce steam that can be used directly to provide heating or to generate electricity. Many countries have been doing experiments in this direction and conventional geothermal technology focuses on energy production from rare, near surface, hot spots, that are sources of steam or hot water. Say for example, in Himalayas and other places people are aware of a the hot springs that exist and people, if they have some information about the hot springs, can it be used to obtain geothermal energy, is something that people are also looking for because, say you have a hot spot in Himalayas which has no electricity. Possibly, that is a good option to irrigate, to provide electricity to villages near by without too much of effects on other lives or other issues. So, the vast majority of the world's accessible geothermal energy is found in hot dry rock and the reservoir must be an engineered for energy production.

Actually, the thing is, it is not, it is the hot temperatures are exists about, as I said much deeper and you need to have engineering systems to recover the heat from deep start or within. So, what you call, you have enhanced geothermal systems and what you call, we hydraulically fracture the formation to increase the hydraulic conductivity and surface area for heat exchange like heat has to come out. So, you need to hydraulically break or fracture the formation. So that, the heat can be recovered. Of course, one should look at a long term consequences of fracturing and also its climate, its effects on subsidence and there could be many issues people have not understood. Though, people have been mentioning about the use of the geothermal energy now. So, the use of geothermal energy is an appealing strategy for the reduction of carbon emissions. Except for the construction of the power plant itself, carbon emissions from geothermal plants are virtually nil. So, what it means is that, you are just tapping the energy that is available and trying to direct to places where you need it.

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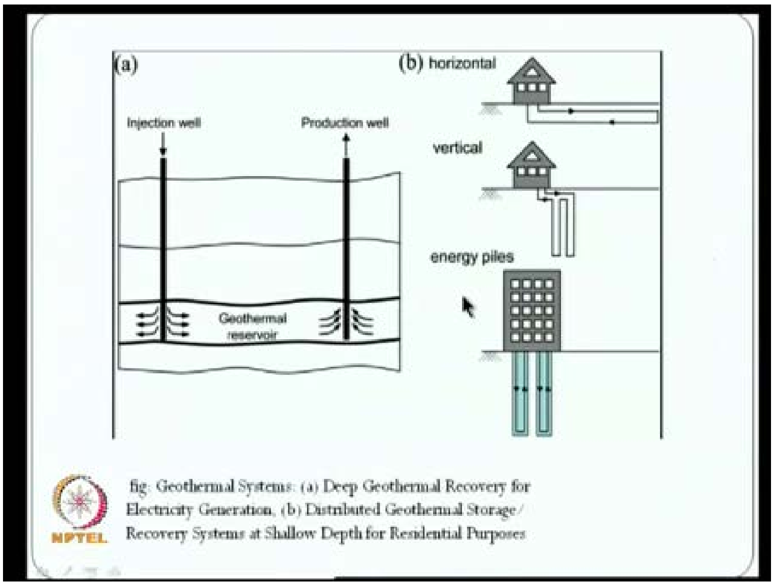

Like say for example, this is a typical figure. You have at the deep temperatures, you have injection wells. Then, you have a production a wells, where you can recover that energy. You have a deep geothermal recovery for a electricity generation. Then, there are also ways of distributed geothermal storage and recovery systems at shallow depth for residential purposes. So, there are certain issues where for houses, say particularly in a places like Himalayas or even UK and other places, where the climate is very cold in winter, people use room heating which is quite a source of energy, which is a big source of energy. I mean consumption of energy and people have been really looking at this sort of options, where you try to obtain the geothermal energy from ground and even use it for room heating.

This is for houses in the apartments. In fact, people have what is called energy piles. I had to, there are couple of groups working in the world, like I am aware of the work that is being done by in UK, where particularly in university of Cardiff. Where, they think that the energy piles could be one option to reduce the load because of the room heating requirements. And some municipalities even say that, our strategy is to have energy piles as a source of energy and eliminate the need for a having room cooling systems and heating systems, based on this type of conventional systems by certain periods, say for example, 2020. I know, I do not know how much is it realistic. But then, people have been making efforts to see, what is a amount of energy that one can recover. There is another place, where I was in Monash University in USA, where under the guidance of professor Malek Bouazza, people have been looking at the energy. The pile acts as a the source of you know, it has certain, it is a steel pile in which, you try to tap the energy from within ground and see that, you are a trying to estimate, how much is the energy that you can get from the underground sources.

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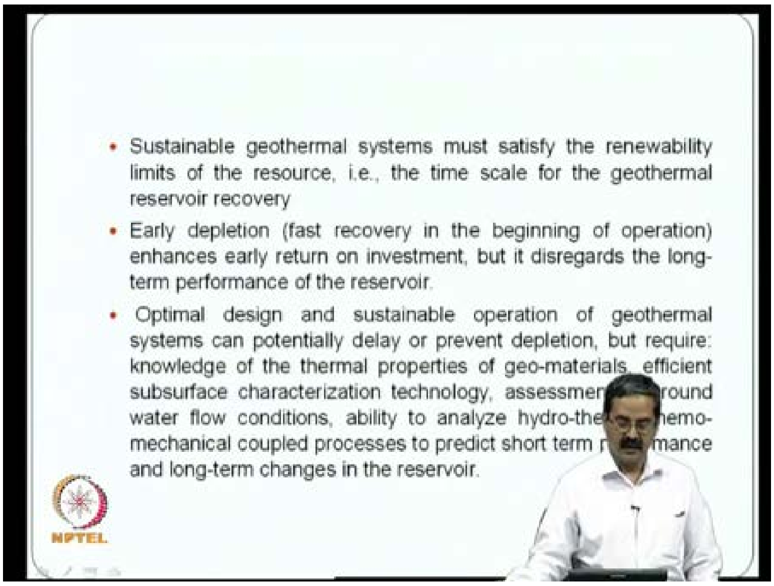

So, these are all some examples. And very importantly, whatever you do like, you are looking at a sustainable geo thermal systems which means that, they should be useful in terms of you know, they must, it is a source of renewable energy, number 1. It cannot be an energy that gets exhausted. So, you must have a time scale for this systems, you know say for example, how can you make this geothermal systems very effective in ten years, like one is serious issue that I always feel is that, the apart from geothermal energy, solar systems. In fact, old energy systems, have certain impact where you know in India, it is common fact is that, in many villages, you do not have power in summer and summer you have sun which is burning. So, at the 45 degrees temperature and if you have some sort of heat recovery systems, energy recovery systems and also the proper piling, proper foundation systems where the energy can be stored, whether in the top and bottom, and there could be a sort of a system where for a some years based on certain calculations.

If you can establish that you do not need energy from the convention sources and the energy from bottom, the geothermal systems or even from solar systems is sufficient, will be a big contribution. I will like to give an example on this connection. There was a one field trial that was, the field trials are being conducted in a Ahmedabad where you know, conventionally we know about canal lining and we estimate that the canal lining, we will live proper canal lining systems will lead to reduction seepage. So that, the water that is being carried by the canals reaches a destination and always people have a prediction, some 20 percent loss, losses they expect in water transported.

Which is, say for example, if you are trying to transport some between two places or fifteen TMC, I mean 1000 million cubic feet of water between two destinations. 15 is a unit and you have 12 as a number that you need to consider. And you expect about 3 tons being lost for, because of evaporation. What was tried in Gujarat was that, they were trying to cover all these canal tops with solar panels, with the result that the solar panels that are there, you can directly tap all the energy from the sun and also, they act as a cover to reduce the evaporation losses.

So, that is an wonderful idea that people have been trying to use. And so, in one shot, you are able to reduce the so called evaporation losses and also reduce a power required for additional 3 ton, 3 TMC feet of water, which is something very good, like you are able to. And then, apart from it, the biggest gain was, they trying to get the electricity from the solar panels that are being used as covers and all the villages nearby can be electrified or energy can be supplied to all the villages nearby. With the result that the requirement that the particular area will be much less. It is an wonderful thing though, it is not directly, does not involve in geotechnical principles. The fact is that the common sense applications of energy systems have been made use of, in this case to see that the energy needs can be really, you know energy required can be little bit lessened.

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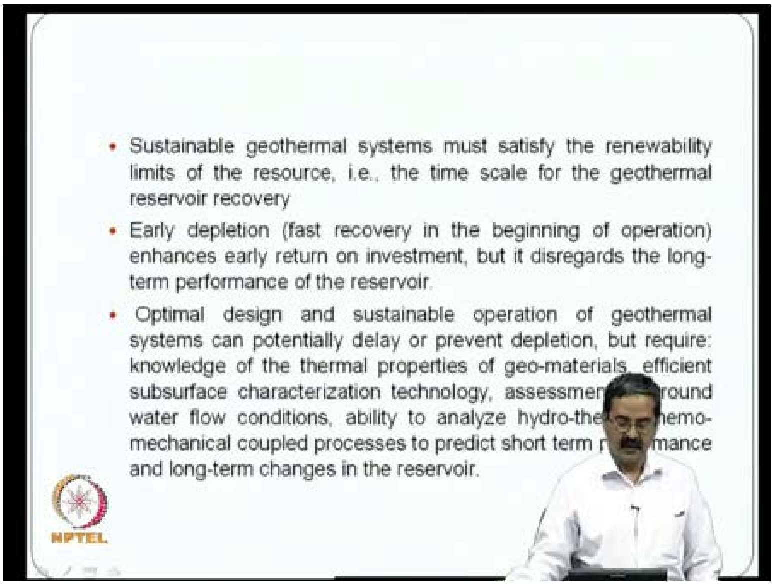

So, this is what I meant by sustainable geothermal systems. And so, in general, definitely, geothermal systems you need to really, they should be sustaining for about long term. Say for example, if you are looking at the geothermal energy, definitely, you must be able to estimate the time scale for the reservoir. Then, early depletion is another, that has a problem like for example, you have a particular source and there is a problem that the energy gets exhausted quite fast. Then, one should be careful because the fast recovery in the beginning of the operation enhances early return on the investment. But this regards a long term performance of the reservoir. So, you should strike a balance between the energy, the depletion of the you know or for example, you would like to store all the energy in terms of the watts to a particular area. But, you should be able to judicially have combined the needs as well as the capacity.

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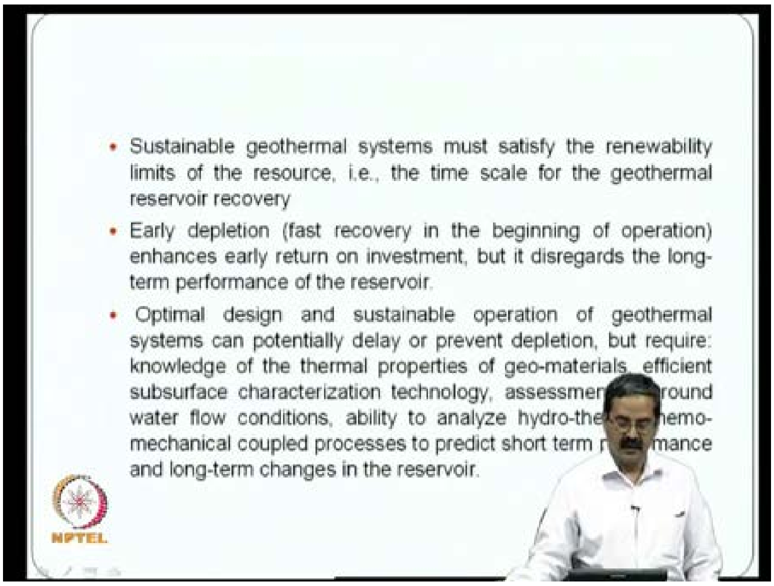

They should be, it is all are very intricate issues. The capacity that one can have in a particular system and also the demand that you can place on the system is something that one needs to assess properly. And people have not understood completely, some of the systems and what I want to say is that, these are all the areas that are governing the future. So, one should look at, in all geotechnical engineers or the ground improvement engineers should look at devices, say if somebody is going for a piles as a source of energy like as I said, thermal piles, one need to understand, instead of the use of stone columns to improve the bearing capacity is one thing. But, use of a steal pile or some sort of thermal pile and then, trying to recover heat or bring the heat to ground is something that is very innovative.

So, one needs to understand lot of dynamics. Say for example, people needs to knowledge of the thermal properties of the geo materials. Like hydraulic, the heat conductivity of the materials, then efficient characterization of the sub surface, the materials, the assessment of ground water flow conditions.Like you know, water has a significant role in a temperature reduction and increase and all that. And more than that the ability to analyze a hydro thermo and mechanical processes, like you have number of processes here. One is you know the water related to and then, thermal effects and also the chemical effects, the mechanical effects, they are all coupled in one sense that you try to recover heat from one source, which is a function of the water as well as the temperature and also, there could be a chemistry influence as well. And it is a mechanical process, mechanics should be understood very well. Otherwise, the design of the heat recovery systems is quite complex. Because, you need to predict the both short term response as well as long term response.

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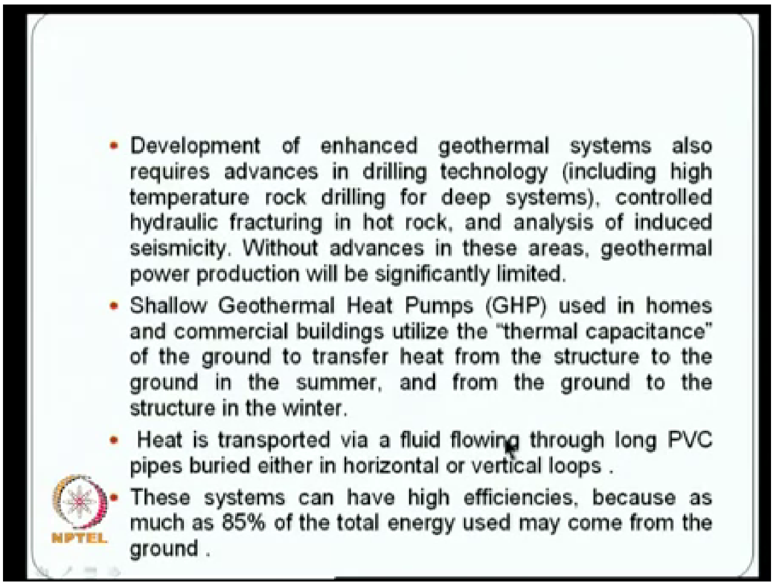

So, a development of enhanced geothermal systems also requires advances in drilling technology, the conventional technologies are not as adequate. So, you may have to go for a high temperature rock drilling for deep systems, controlled hydraulic fracturing in hot rock and analysis of induced seismicity. In fact, see you need to do a hydraulic fracturing, breaking of the rocks in a controlled manner and then, you must see the thing is the fact that, you introduce a fracture leads to some sort of seismicity. Like plate tectonics also should not be affected, like we had a classical case of reservoir induced landslides. That should not be a case here. So, one needs to understand that, there should be a controlled way of doing this particular thing. So, without advances in this areas, geothermal production will be significantly limited. The knowledge that you have, may be you may have lot of ideas but then, if you do not understand or you know exploit in a proper way, the problem is that it may leads to much more serious difficulties than what you initially thought of and one should need lot of careful analysis.

So, the other concept that I just mentioned was a shallow thermal geothermal heat pumps used in homes and commercial buildings utilized the thermal capacitance of the ground to transfer heat from the structure to the ground in the summer, and from the ground to the structure in the winter. This is what, people are trying to use in the case of, what you call the UK and other places. You try to have a thermal capacitance systems and beneath the buildings, so that you have some sort of transfer mechanism. You try to store, when it is available and also when you need it, take from the storage stored energy.

So, this is a concept and this needs a big change in our ground improvement knowledge and thinking and even foundations, the way that we design and all that. So, in most of the cases, the heat is transported via a fluid flowing through the long PVC pipes, buried either in horizontal or vertical loops. These systems have very high efficiencies, because as much as 85 percent of the total energy used may come from the ground. You know, the thing is some of the people have seen that, though I mean there are some calculations made on this but one should, they say that, there are highly energy efficient systems. But, you know the people have been using it.

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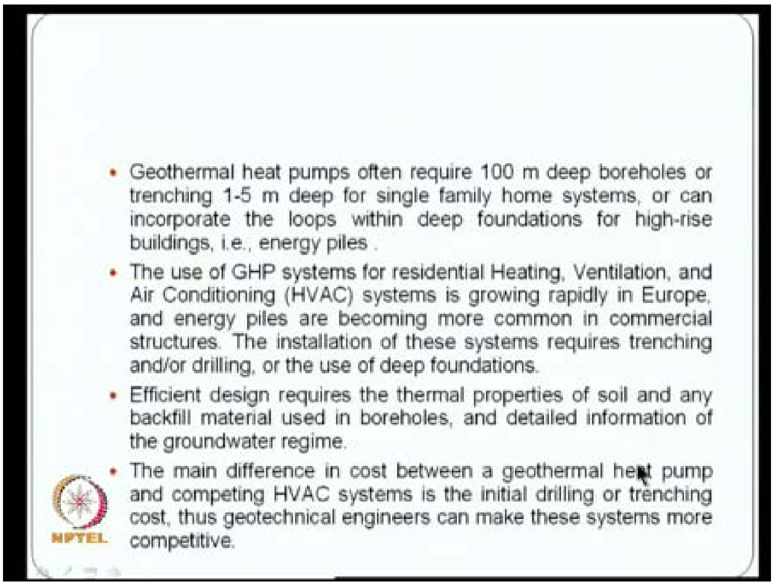

The geothermal heat pumps often require more than 100 meter deep boreholes or trenching 1 to 5 meters deep for single family home systems, or can incorporate the loops within the deep foundations for high-rise buildings, that is, energy piles. So, the concept of this energy piles is what have being followed in UK and other places. This was in fact, I highlighted in one of the earlier lectures in the beginning that, when I discussed about the scope for ground improvement. So, you can see that, it needs a very deep boreholes, also trenching, you know when a deep level, which is not easy like if the cost of the bore holes and you know it needs to understand that, this is quite expensive as well.

So then, even you know having a loops within the deep foundations particularly, if you are trying to go for pile foundations, you need to have a system of piles, you know actually the energy piles. So, the use of this systems for essential heating, ventilation and air conditioning, like say for example, heat, vent and air conditioning systems is growing rapidly in Europe, as I just mentioned. And energy piles are becoming more common in commercial structures. In fact, you know people have to maintain, you know in an apartment like you have an apartment. If the energy requirements are going to be too high, the problem is that it is not easy. So, the efficient design requires thermal properties of the soil and any backfill material. The thing is that, these systems need trenching and drilling and the use of the deep foundations.

The efficient design requires thermal properties of the soil and any backfill material used in boreholes. So, this is say for example, as I just mentioned, the clays and sands and varieties of materials, how varieties of, you know one needs to understand the thermal response of this materials and also the detailed information of the groundwater regime. The main difference in cost between a geothermal heat pump and a competing as I said, heating, ventilating, air conditioning systems is the initial drilling or the trenching cost plus, thus the geotechnical engineers can make these systems more competitive.

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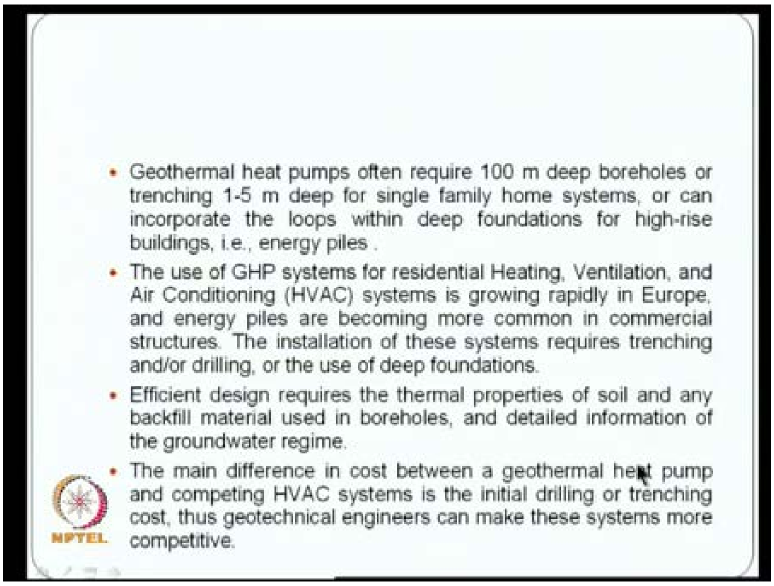

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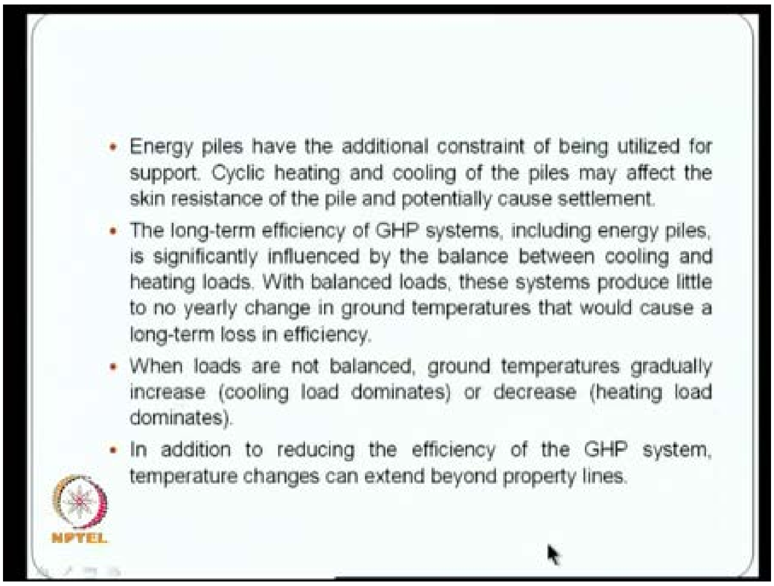

Actually, the thing is you have the two issues here. The geothermal heat pump is one thing, GHP. And also the other one is also like, you know, you need to understand these two systems very clearly. And say and then geotechnical engineers have to understand lot of mechanics here, of the heat transfer in soils. So, energy piles have the additional constraint of being utilized for support. This is where, you know the concept of geotechnical engineering comes into picture. And the cyclic heating and cooling is something that affects a skin resistance of the pile, like as I just mentioned, steel piles are being used and definitely, when you have cooling and heating of the piles, that will affect the skin resistance and may have some sort of settlements that are there, because of this.

And the long term efficiency of the GHP pipes or the systems including energy piles is significantly influenced by the balance between the cooling and heating loads. Like what is the cooling and heating loads, you know the thing is as I said, you know the piles or the foundations, that are now acting as energy recovery systems or energy storage systems are now subjected to a cycles of cooling and heating. So, we need to understand how is the efficiency of these materials, the cooling and how is the heating influences the efficiency of the heat transfer. It is something that one should understand. So, you need to understand the loads that one can expect and also the ground temperatures like you know, how the ground temperatures also have a role in this.

So, in addition to reducing the efficiency, sometimes what happens is that, if the loads are not balanced, the ground temperatures gradually increase like see, what is required in this case is that as I just mentioned, we need to understand the loads like cooling and heating, you know what it means is that, when as I said in a particular winter and summer, in the case of winter we need heat. So, there is lot of load. But in the summer you know, you have, you are trying to recover that capacity. So, you have to see the balance in such a way that, they do not you know your design of the system should not lead to inefficient design. And when the loads are not balanced, ground temperatures gradually increase and decrease in dominates. In addition to reducing the efficiency of the system, pumping system, the temperature changes can extend beyond property lines. One should be careful about it.

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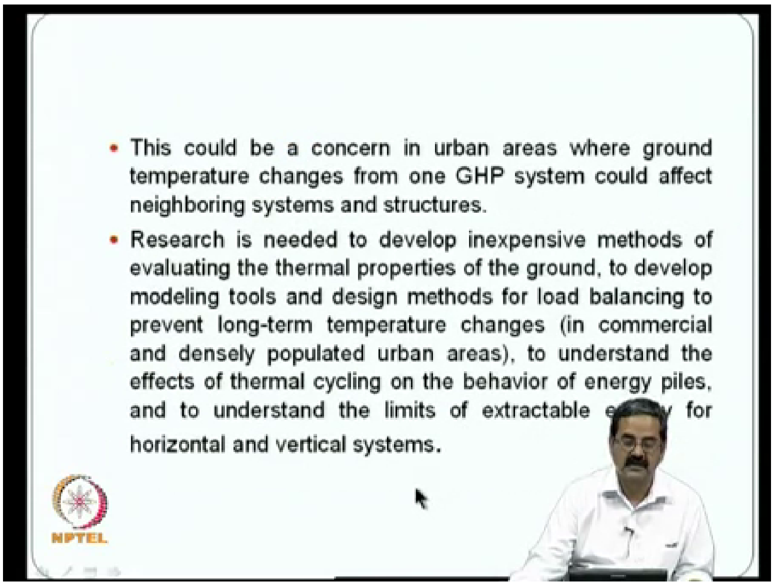

And see particularly, you know the reason is that, why I am mentioning is that, people have been working on these lines. And of course, we in India at least you are not aware of the impact that it has and definitely, use of this, you know systems in highly congested areas like you know, in Europe and all that, where the Urban localities are more populated. They have a significant issues because the ground temperature changes from one system to another thing could affect the neighboring systems and structures. Like, you know similar to, you try to excavate a building here and then, remove a some soil, definitely it affects the stability of the next building. So, in that sense whatever changes you make here, in the energy systems have to, should not affect the next one and that is a very serious. So, there are lot of balancing that needs to be done and research is required to develop inexpensive methods of evaluating the thermal properties of the ground.

In fact, now, we should say that we do not have very good methods of in-situ methods. In fact, we should go for in-situ methods of heat conductivity of the soil and all that. And also develop modeling tools and design methods for load balancing to prevent long temperature changes. You know, it is like you need to even use signal based, signal processing techniques to see that, if there is a so much temperature raise, suddenly you know, there should be an automatic switch off and switch on systems like that, where the objective is essential to get a balance. You know, you can only take what you need. So, that is how a balance should come or store, what you can store. And in excess of excess of heat also leads to problems and deficiency also, leads to some problems. So, these variations need to be catered for, in the design of the heat recovery systems and the systems. So, the other the other thing was that I just mentioned, the effects of thermal cycling. It is something that, it needs to be understood and all these things have to be examined in a careful manner.

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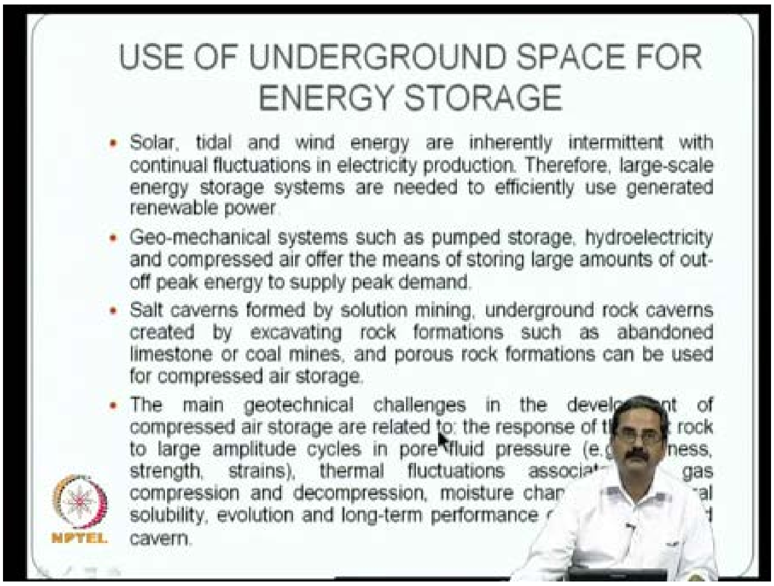

So, uses of underground space for energy storage is something that people have understood very well, in the recent times. And particularly, in the area of rock mechanics and geological engineering, people have been doing lot of work. May be in the broad spectrum of geotechnical engineering, it is not attempted. But at the same time, if you will see, have a bigger picture, global picture, people are looking at geo engineering or ground engineering in a way that, so that, the energy can be stored. One important reason is that solar, tidal and wind energy are inherently intermittent and they have lot of fluctuations in electricity production. So, what people are trying to have is they need to have lot of energy storage systems in the ground to efficiently use a generated renewable power.

So, you have lot of energy recovery systems, you need to really store them in a way that, it can be done properly. So, geo mechanical systems such as pumped storage hydroelectricity and compressed air offer, the means of storing large amounts of out of peak energy to supply peak demand. You know, what people have been trying to say is that, you store the all the energy or hydroelectricity is one way, like we always have been doing it and compressed air. In fact, you know, you have to store this compressed air. Compressed air as a means of energy, is something you know compressed air has lot of air pressure, the pressure energy. So, that can be used as a store house. So, that all the energy that you have, can be stored to supply when there is a peak demand. Then, there are people have been looking at salt caverns formed by solution mining underground rock caverns created by excavating rock formations, such as abandoned lime stones or coal mines. And porous rock formations that can be used for compressed air storage. In fact, this is an abandoned main, mine area and there is area, storage area. You need to really properly redesign to see that, it can work as a place where compressed air storage, why not, it is a very complicated job.

But you need to you know work towards that and people particularly in France, have been working on these things. So, the main geotechnical challenges in the development of compressed air storage are there. For example, the response of the host rock to large amplitude cycles in pore fluid pressure, stiffness strength and strains. Actually, what is happening, when you have, when compressed air has lot of pressure inside and the in-situ, if you store it in a particular material, it exerts lot of pressure and then, so the stiffness strength and strains that are induced because of the compressed air pressure needs to understood in a proper manner. Then, thermal fluctuations associated with a gas compression and decompression, moisture changes and minerals solubility, I mean even you know some of the rock materials, they are soluble. So, one need to understand and evolution long term performance and underground caverns are very important. One should understand that these are all very another issue that a ground engineering or a ground, you can you know both the title of the course is ground improvement. These are all, it is ground engineering or what is called geo engineering.

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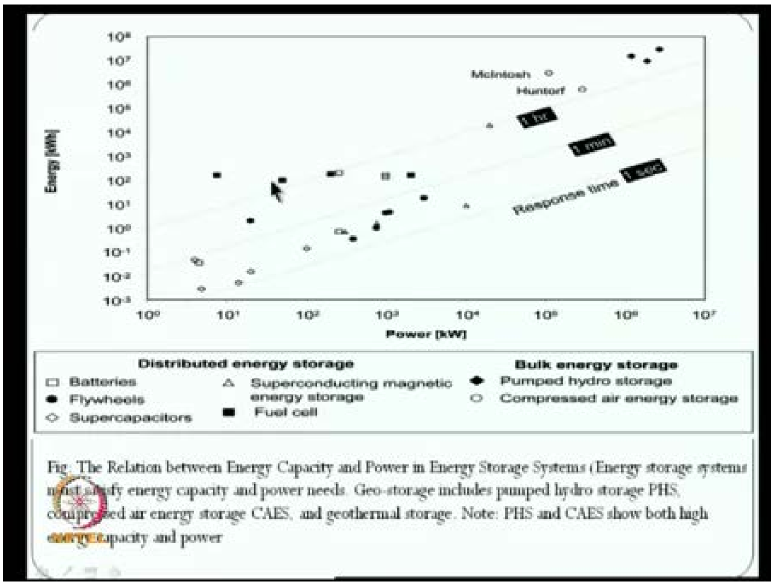

So, this is some example of how the response time, for different energy storage is there. Say for example, energy so what hours and their response time and you can see power and then, the energy. And batteries have very quick response systems because batteries you know, their response time is faster. Then, you also have a fuel cells, they are somewhat here and pumped hydro storage is somewhere here and a compressed air energy storage is here. What I meant was that they may have, you know low response time. So, definitely this is some sort of understanding, you know actually, similar to stand up time, stand up time in soils like you know, sands have a less stand up time and clays have a more stand up time, when you do an excavation. So, these are all some sort of work people have done to understand, what is going to happen, when you are trying to how is a response time. So, this is also you know, say for example, this is also quite important in the case of a different energy systems.

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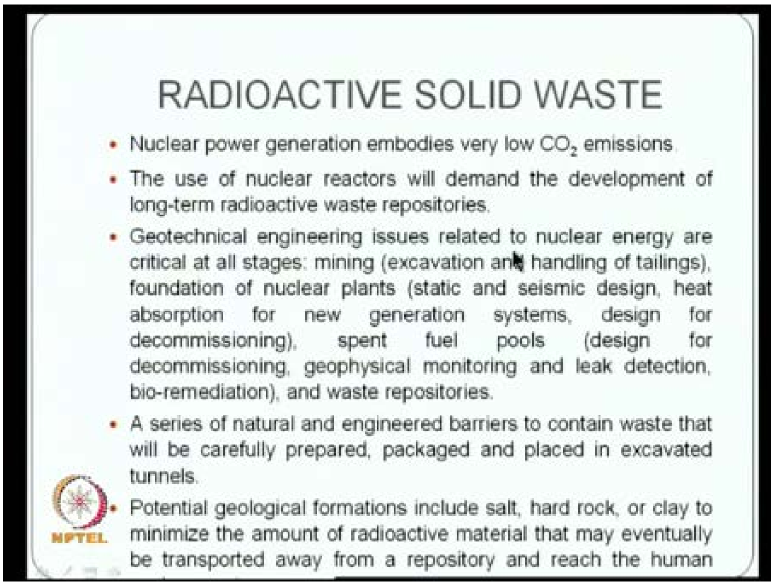

Other important point that I would like to say is that, people have been looking at radioactive solid waste and you need to contain that in a proper way and nuclear power generation embodies very low CO2. The advantage of the nuclear radioactive waste is that, it has a low carbon emissions are there. And the use of the nuclear reactors will demand the development of long term radioactive waste repositories. You know, people have been working on this. And people, though the nuclear energy is a thought of as a serious alternative, there is a setback, because of the incidence of the Earth quake and Tsunami in Japan.

But, I think still people are trying to pursue that and it is more of engineering and it is very critical engineering and definitely, geotechnical engineering has a big role to play in trying to address the issues of nuclear energy at all stages. Say for example, mining of the radioactive waste, how do you handle that. Foundations of nuclear power plants, static and dynamic design, heat absorption for new generation materials, spent fuel pools. You know, how do you handle this spent fuel and geophysical monitoring and leak detection, bio remediation, waste repositories. There are many issues that you have and a series of natural and engineered barriers to contain waste that will be carefully prepared, packaged and placed in a excavated tunnels or something, that people have been looking at. But then, the stability on the engineered barriers is you know, needs to be assessed through number of experimental studies and detailed studies and simulations. This is actually, people in Baba atomic energy center and department atomic energy, they handle this. And of course, the role of geo engineering or ground improvement or geotechnical engineering is quite significant in all these issues. And potential geological formations include salt hard rock or clay to minimize the amount of radioactive waves. That may eventually be transferred away from a repository and reach a human enrollment.

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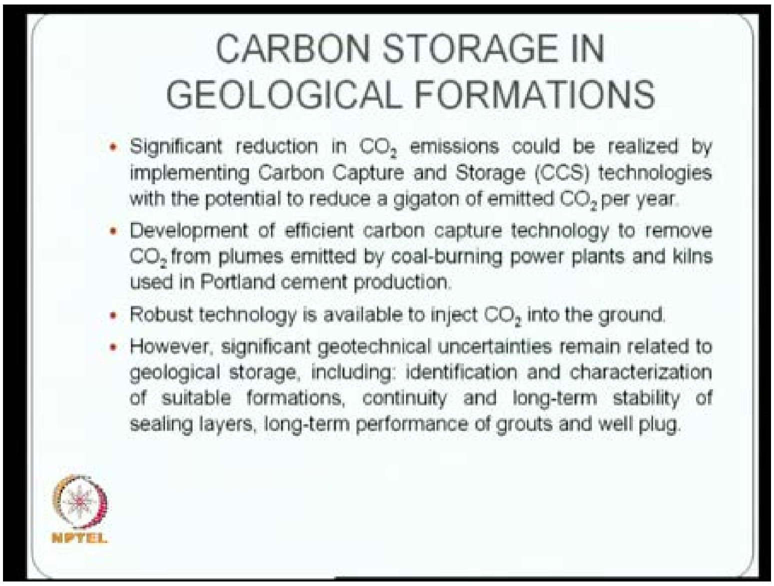

So, many of these environments need to see properly and as I just mentioned, significant reduction carbon emissions could be realized by implementing carbon capture and storage methods and so that, you know the objective is that, you know that there is a carbon emissions, try to capture it. So, that it does not really heat the atmosphere. That is another way of people are working on that. And development of efficient carbon capture technologies to remove CO2 from plumes emitted from coal burning plants and kilns used in Portland cement production. Something that people have been looking at it. A robust technology is available to inject CO2 into the ground. However, significant geotechnical uncertainties remain related to geological storage including identification characterization of suitable formations, continuity and long term stability of the sealing layers, long term performance and grouts and well plugs. There are so many issues that people have been trying to do.

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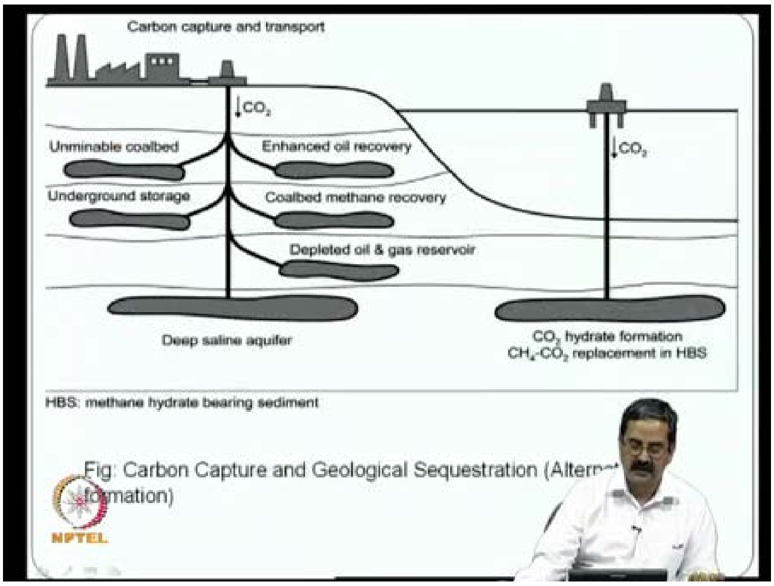

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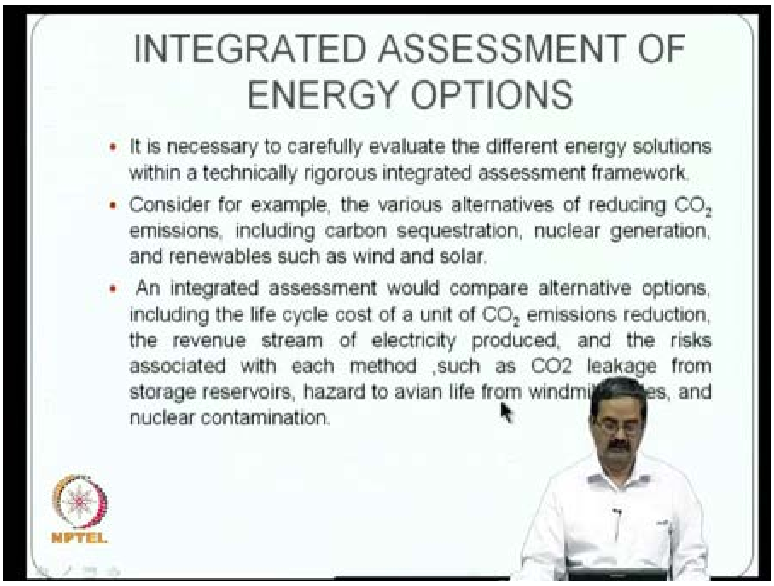

Say for example, capturing of the carbon, you can see from a particular plant, it can, how do you do that. This is all one schematic way, this is another schematic way of trying to capture the carbon at various levels and this is what we call carbon capturing geological sequestration. So, people need to understand the energy options in a different way and also see that there is some integrated reviews of various ways of reducing the carbon emissions and also carbon sequestration, nuclear generation and renewable sources. So, you should have an integrated way view of the carbon emissions as well as it is a serious issue. One should understand them in a proper way. Otherwise, if you do not have this, is we saying that we do not know what right hand is doing, what left hand is doing, right hand does not know.

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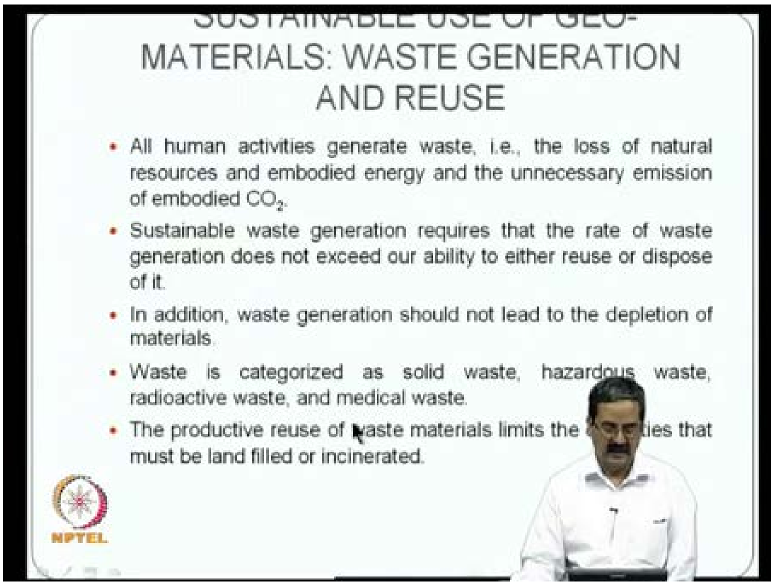

So, that should not really happen, in the case of energy and people have been looking at a sustainable use of geo materials like again the use of waste, I think you know solid waste has. They have been, you know people have been doing that may be this, I will address that in a another lecture, where the sustainable waste generation requires that the rate of waste generation does not exceed our ability to either reuse or dispose of it. Like particularly in, say for example, in the case of land fields or the hazardous waste materials. So, you need to even contain the waste, reuse a waste in a proper way that the waste is used properly.

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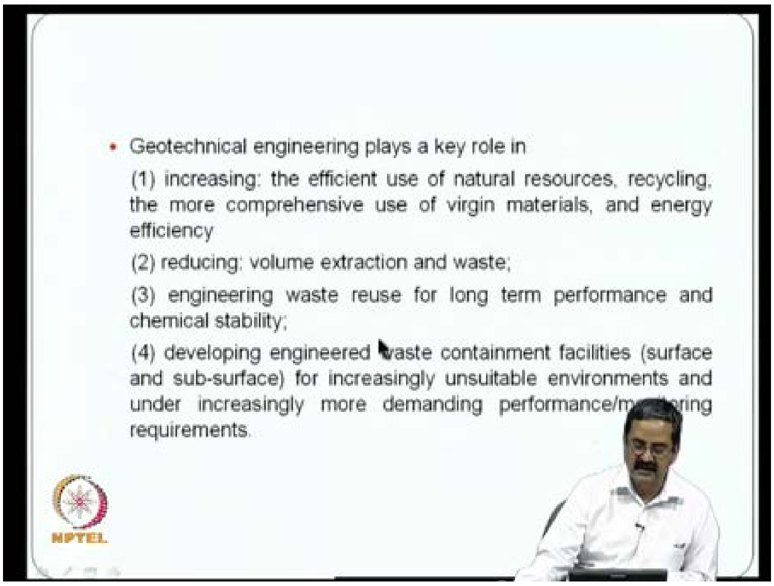

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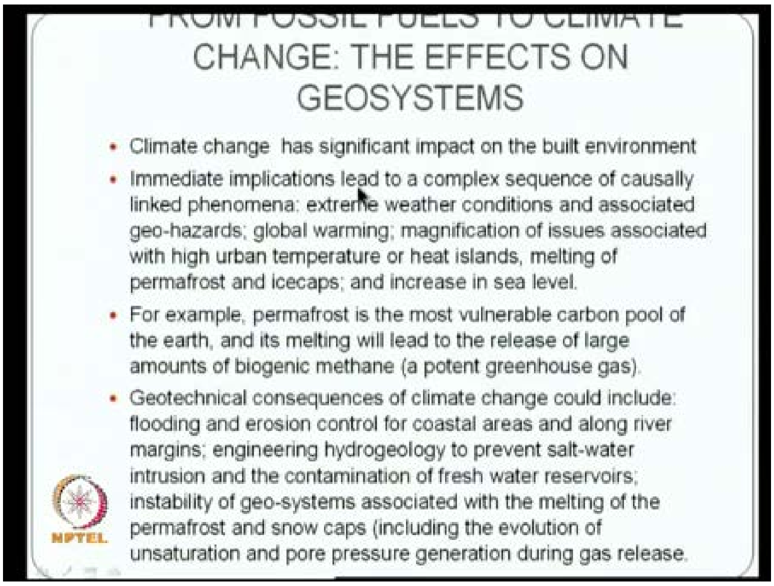

So, that way the geotechnical engineering plays a big role in the efficient use of natural resources, recycling, more comprehensive use of the virgin materials and energy efficiency. It reduces a volume of the waste, engineered waste reuse in long term performance, developing engineered waste containment systems, which is very important. And there are lot of challenges and definitely in the climate and to prevent the effect of the climate change, the geotechnical engineering is quite helpful. The effects on geo systems is quite helpful.

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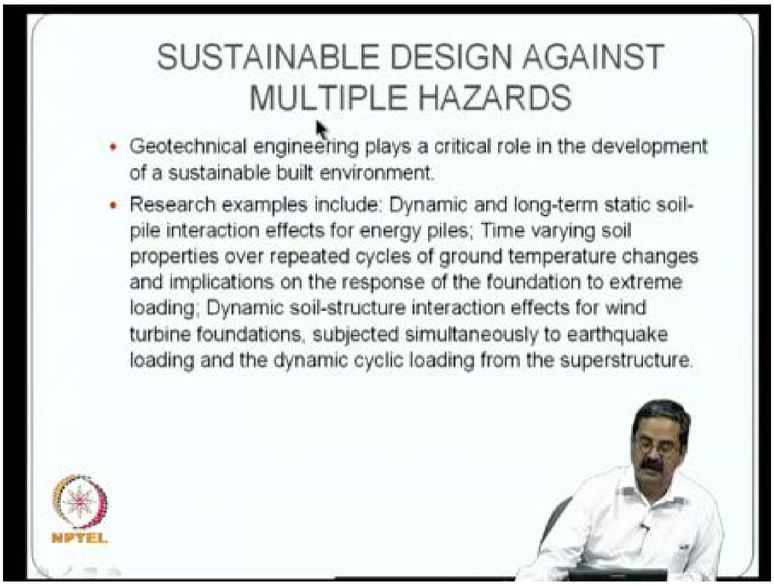

And this is a serious issue and sustainable design against multiple hazards is something that also is a serious issue. Because, like when you do something else, something else happens. Like you know, you try to do hydraulic fracturing, it should not lead to earthquakes. This is something that one should understand. So, sustainable design is something against that is what, I meant by multiple hazards. Say for example, dynamic soil structure interaction effects for wind turbine foundations and they may be subjected to Earthquake loading and dynamic cyclic loading from superstructure. So, some of this as issues need to be addressed in a simple way.

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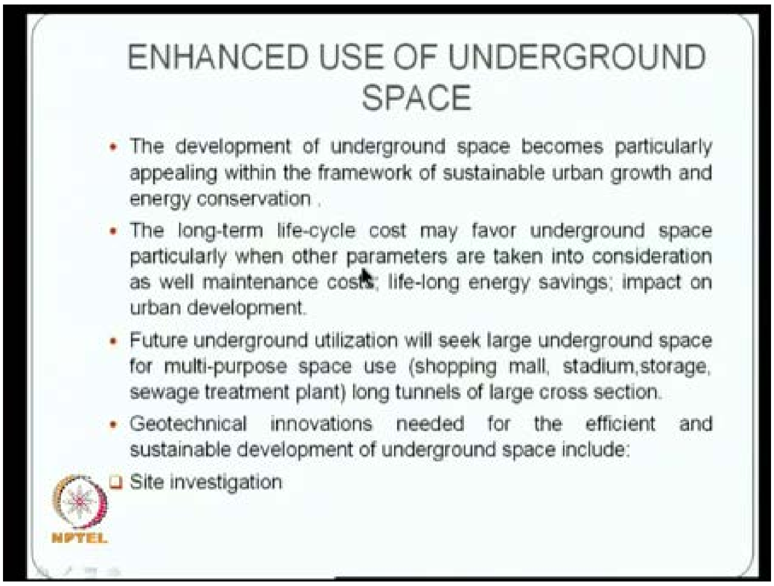

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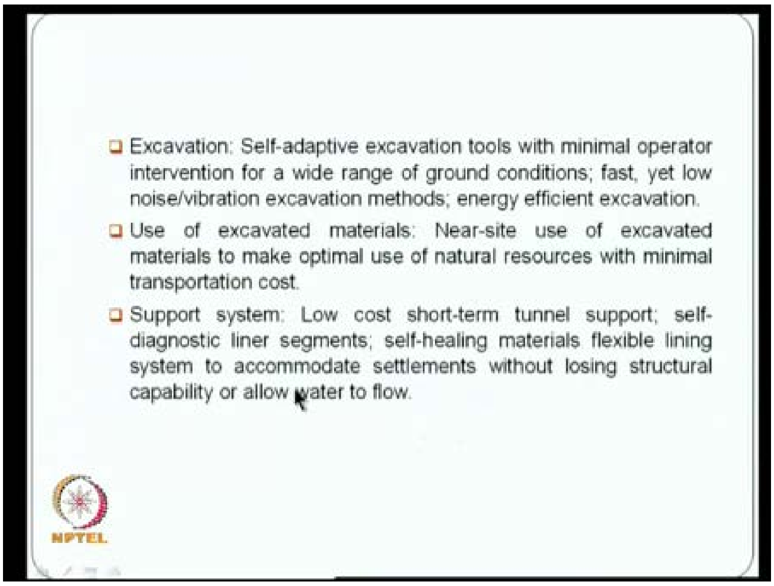

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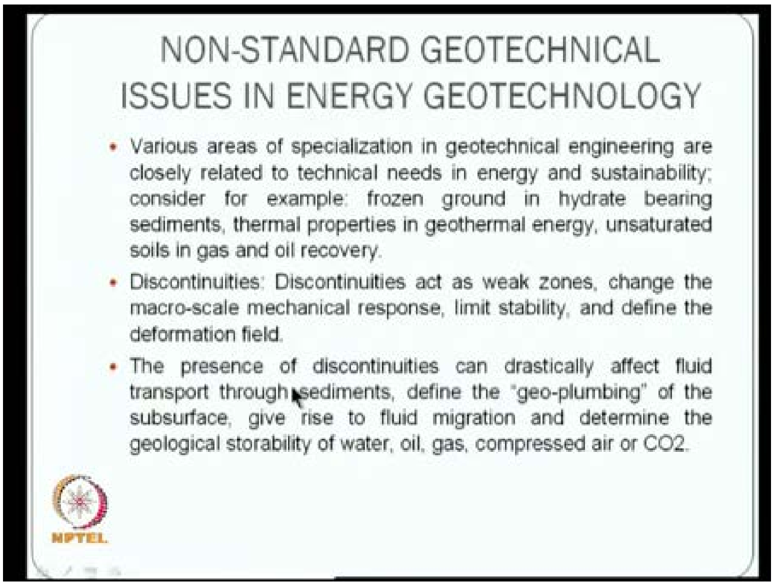

And enhanced use of ground space is another important issue. And so, proper geotechnical engineering, life cycle cost analysis, underground utilization, innovation should be there, (( )) should be there. There should also be self-adaptive tools, excavated materials and good support systems. And you also have, whatever is considered a standard, may not be applicable here. So, you need to have, in innovative ways of doing things. One should look at, you know many innovative methods of geotechnical issues in energy geotechnology.

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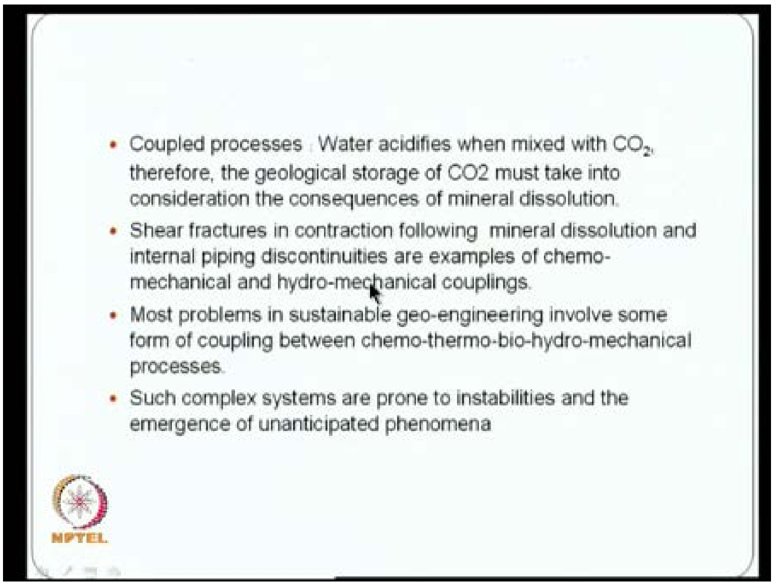

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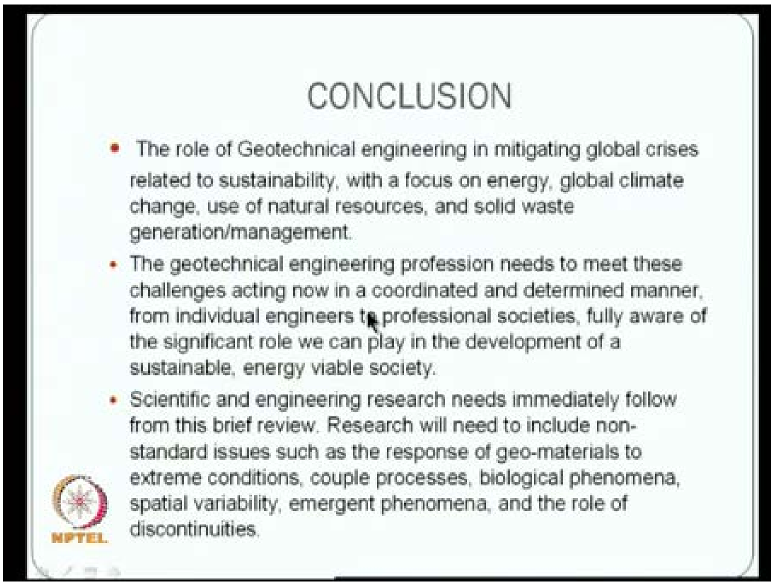

And you know, say for example, coupled processes, shear fractures and most problems in sustainable geotechnical engineering or something very complex. One should see that, there also biological phenomena and also, what should spacial variability of many of the geological properties and geotechnical properties, very significant and one should understand that, they have lot of things that one can do that. So, what I would like to say is that geotechnical engineering has a significant role in controlling this and I must say that the people have to significantly use, in the geotechnical curriculum and you know, have a look at it. These are all some references, thank you.