Physics of Renewable Energy Systems
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Lecture: 01
Introduction and Relevance of the Course

Hello, welcome to the course on Physics of Renewable Energy Systems. In today's class, we will be giving you a brief introduction about the course, and we will also be giving you the relevance of the course in today's society and why is it important to study this topic.

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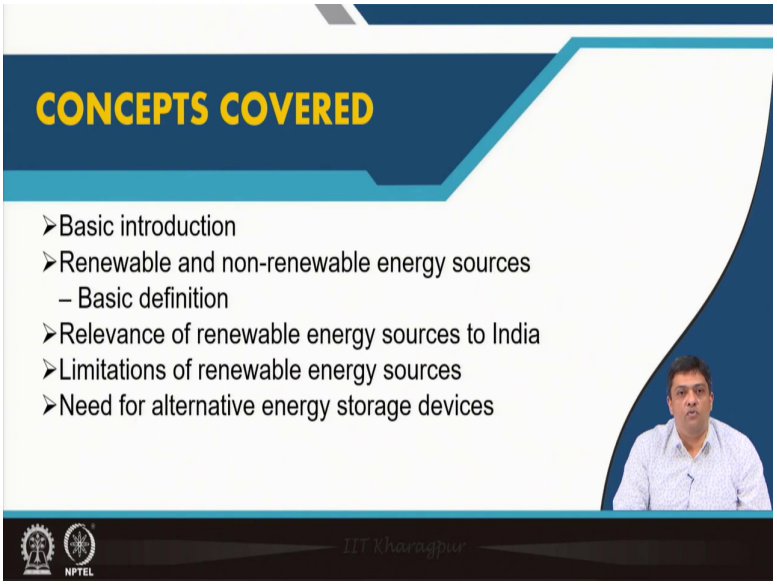

Now, what are the concepts which are going to be covered in today's slide, we will be covering the introduction, the difference between a renewable and non-renewable energy sources would be described to you, and then we will also like to give a basic definition to these terminologies, and why renewable energy systems or sources are relevant to India.

We will stick to and focus to our needs in India. Is everything good about renewable energy systems and sources, or there are some limitations. We will also talk about the limitations of renewable energy sources. And how do we counter these limitations, which leads to the essential need of alternative energy storage devices. This is what we are going to talk to you today.

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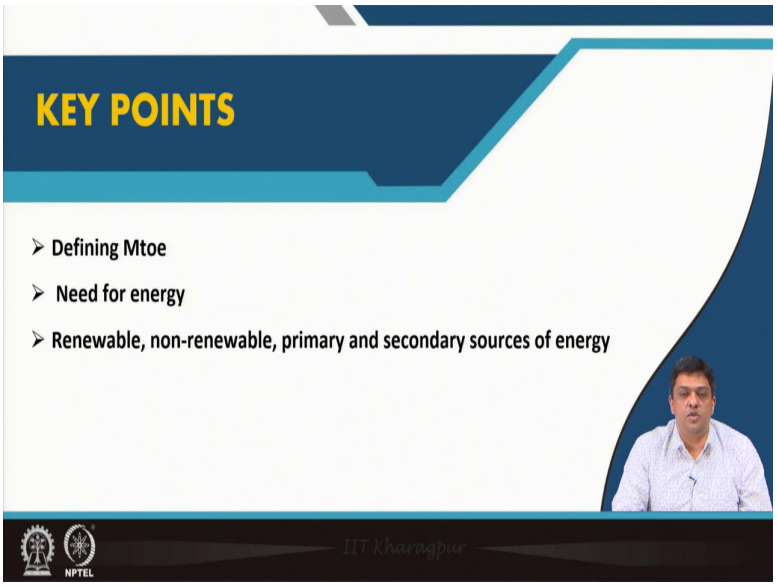

And the key points which I hope you will understand by the time we finish this lecture is the definition of Mtoe that is the Megaton Oil Equivalent, it is the unit in which the consumption of energy is explained. What is the need of energy? Why do we need energy? That point would be clear and you will be able to defend this understanding and the four major topics which we will cover would be based on renewables, non-renewable, and can these systems be sub classified under the headings of primary and secondary sources of energy.

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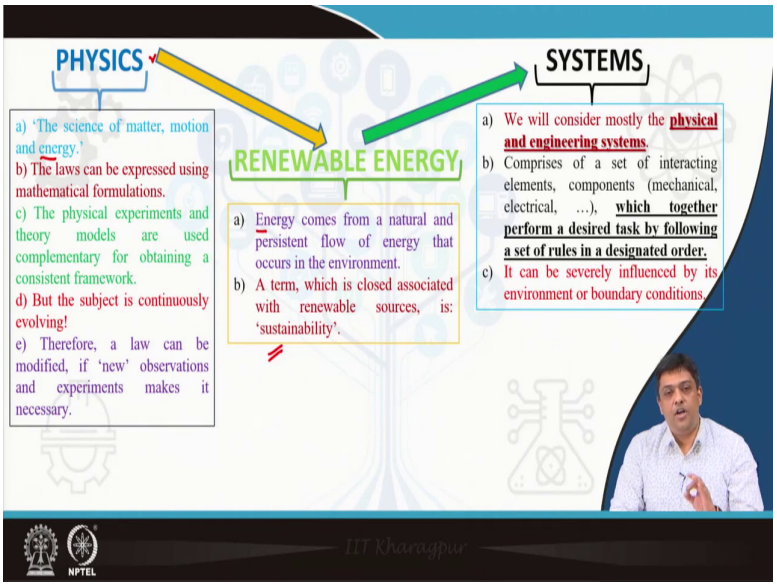

So, this is the course, we are going to talk to you about. Physics of renewable energy systems. So, there are four basic terms which are there, physics, renewable energy, and systems. So,

how are they related, why do I talk to you in these terms. Let us see, why we talk about physics. If you look into the definition of physics, it is the science of matter, motion, and energy.

So, we like to understand about the matter, how is it formed, when it is being moved from one place to the other or there is a motion, then how do we explain that motion, and the energy concentrations are explained in physics. With that, we also like to give certain set of laws using mathematical formulation, so that we can bring certain exactness in our explanations.

And the whole concept is actually defined by making certain measurements that is physical experiments and then explaining those observations using consistent theoretical models. So, if you look from mathematical point of view consistent means, that a statement is made, then those can be explained by using certain sets of axioms or theorems. So, this is what you will think about a consistent framework.

So, you can explain them using certain set of axioms or postulates and theorems, but as we know that the subject is continuously evolving, we observe new phenomenons that means, a law which would have been proposed earlier can actually modified if we see certain new observations. And there are experiments, which lead to these observations and they contradict the earlier beliefs. So, this is the way physics is developed and the subject of physics is explained to a normal interested person.

Now, renewable energy, what is renewable energy, these are the energy, forms of energy which come from natural and persistent flow of energy that occur in environment. What do we mean by this definition? So, these are the sources, which are naturally occurring along with that there is a continuity in the supply.

So, you have a continuous supply of energy from these natural sources and the moment, we get the term energy, you see, there is a common term which comes into the first two definitions, physics is the science of energy. So, we understand how energy is conserved or it is transformed from one form to the other and in renewable energy, we are talking and focusing primarily on energy.

So, we must use a lot of laws which are explained in physics. Along with the requirement of persistent flow of energy in renewable energy or sources, there is an additional term which

goes hand in hand, that is sustainability. What do you mean by sustainability, sustainability means, that these sources are going to be available to us, they will cater our needs as well as they will cater the needs of the future generation without undergoing any depletion or their source will not get depleted.

So, sustainability means they were available before us, they are available to us, and they will remain available to the future generation and they will also cater to the needs of the future generation. And if you look into systems, let us consider the definition of systems mostly to considering the physical and engineering systems, these are basically sets of interacting elements, components or machine parts, which can be mechanical, you can have electrical components, you can have electronic components, which are put together and they are required to perform a certain task, but in a designated order.

So, you have a system which will perform a certain task and the order in which that task will be finished is predefined. So, if we want to have a conversion process, let us say from one form of energy is converted to another form of energy, let us say from chemical to mechanical or thermal to mechanical, then there is a set of protocols which have to be followed before this conversion takes place.

So, can we now explain how this course, physics of renewable energy system is going to be useful to us, yes, we will understand the science of matter, motion of an energy, we will find out, as we go along, we will find out where and from which all sources can we derive these energies. And once we have the source of energy, can we convert it from one form to the other using various systems, so that a particular task is obtained. So, we have, this is the whole description about the subject.

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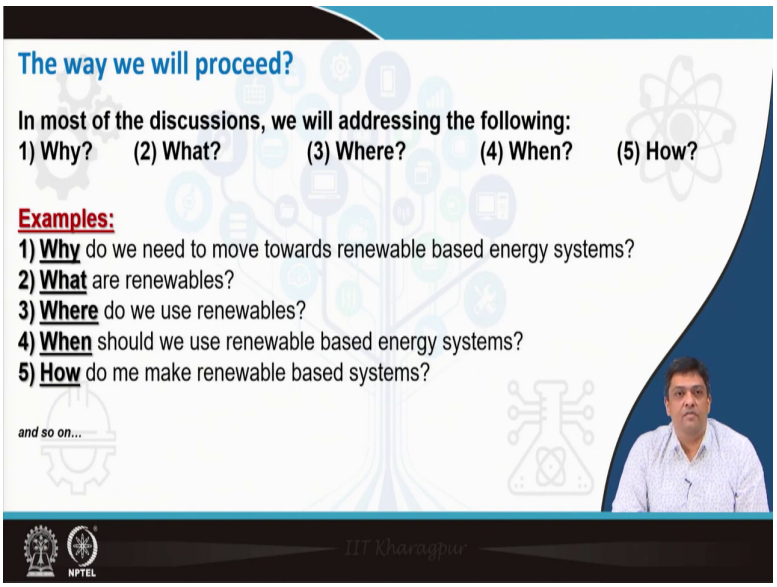

And, I would like to proceed in this lecture by telling you that in all the discussions which we will have in the subsequent lectures and also in this lecture, we will be moving in the class by asking questions like why, why is the most important questions we will be raising, what, where, when, and how. Examples of these questions are like this. Why do we need to move towards renewable energy systems, who told us to move towards renewable energy systems? What are renewables actually?

And, if we can answer these first two questions, where do we use renewables? And once we have defined the first three questions, and also try to found the answer. when do we use the renewable energy systems? And finally, can we find out how to make a renewable energy system which will make use of renewable resource and convert it to a usable form of energy. And this is the type of questions we will ask; we will start from very simple questions and we will build upon the subject slowly.

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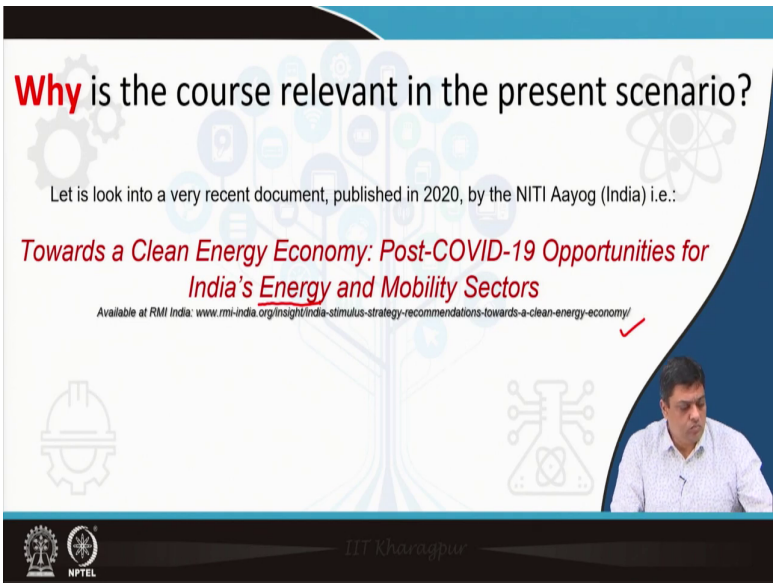

So, let us start. Why is the course relevant in the present scenario to us? As of now, we have our NITI Aayog which tells us and defines the details about India and the future direction where India would like to move. And recently after the pandemic hit us, the NITI Aayog came up with a document which is entitled towards a clean energy economy, post COVID opportunities for India and India's energy and mobility sectors.

So, they have come out with a specific document talking about India's need for clean energy, and how this clean energy is going to address the needs of mobility sectors and the details can be downloaded from the website and the reference mentioned here.

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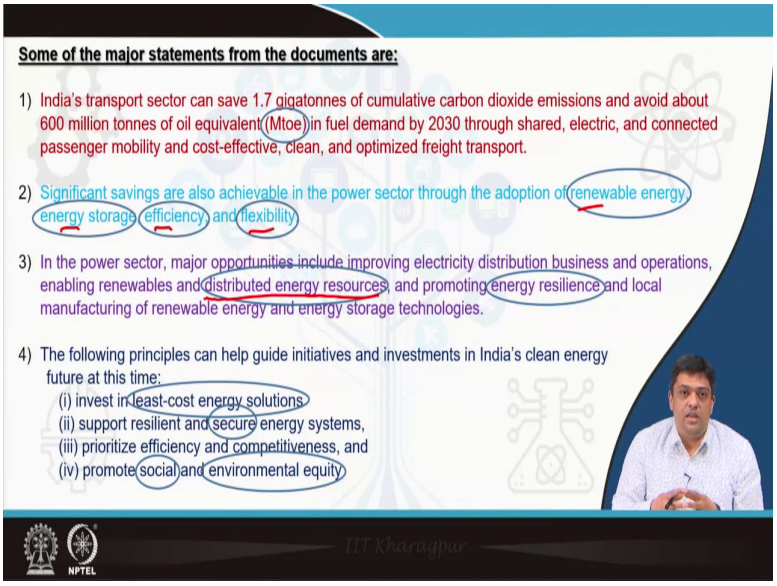

Some of the major statements, which are given in the document are listed here. And I will not read through them, I would give you the basic understanding and we will define certain terms which look to be very easy, but needs much more understanding to explain the relevance to the subject.

So, the document clearly states if you see point number 1, it clearly states that India can save a lot of, let us say 1.5 Giga tons of cumulative carbon dioxide emissions and it can avoid 600 million tons of oil equivalent in fuel demand by 2030, through shared, electric, and connected passenger mobility and cost effective, clean, and optimize freight transport. So, this is a statement, which basically tells you that if you are using clean technologies, we will be contributing in mitigating the environmental changes.

So, we will be somehow reducing our carbon footprint. Along with that, we can save a lot of money and we can move towards becoming self-reliant in power sector if we use renewable energy, energy storage, which are efficient and flexible. So, we have four more terms renewable energy, energy storage, efficiency, and flexibility. These are the terms, which have to be explained and defined with respect to the course that we are trying to explain to you.

And along with that, you will see in point number 3, there is a new term, which comes in distributed energy sources. And, if you have distributed energy sources, you will have to promote energy resilience and local manufacturing of renewable energy generation as well as storage technologies.

So, till now, it was mostly talking about generation technologies that you generate energy, but suddenly you see, now, people are also putting two terms together generation as well as storage are going hand in hand. And why do they go hand in hand we will explain bit later today. And the roadmap, which is mentioned is that we need to invest in these low-cost energy solutions, we must have secure energy systems while ensuring the competitiveness and the efficient use of these systems.

Also, these social and environmental impact should be ensured while maintaining the equity in the whole implementation. What do we mean by that, we mean that we should ensure that when we use these technologies, we don’t lead to changes in social and environmental standards that are at a level lower than that where we are already at! We do not lead to higher

carbon footprint, we do not lead to conditions where the societal i.e. the nearby societies are getting impacted.

And therefore, we must promote social and environmental equity. So, the terms which are new are Mtoe, renewable energy, energy storage, efficiency, flexibility, distributed energy resources, energy resilience. So, although they look to be very easy to be explained, they are not as easy as they seem. And we must spend some more time in understanding each of these concepts. And once these are done, we will proceed to the next round.

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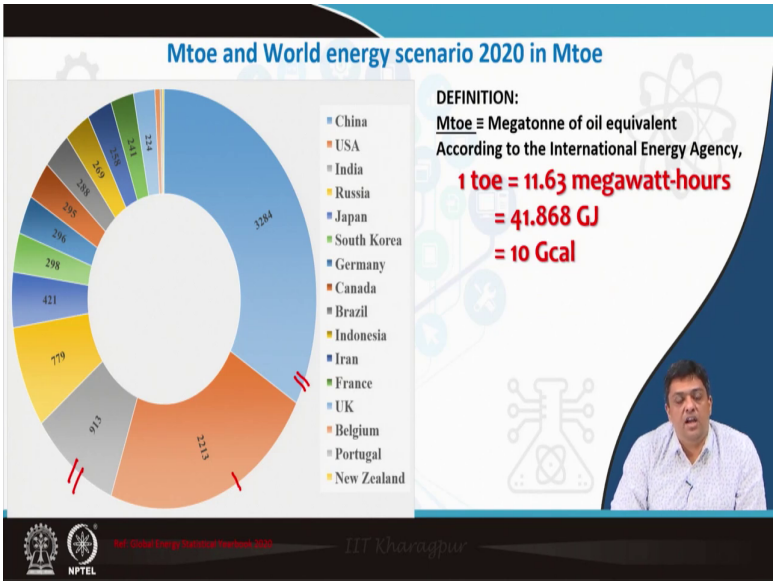

So, according to the International Energy Agency, 1 tonne oil equivalent is equal to 11.63 megawatt hours, which is equal to 41.868 Giga joules or it can also be written as 10 Giga calories. The pie chart on the left-hand side tells you the energy which is produced in various countries. And you can see that China produces something like 3284 megatonne of oil equivalent.

Whereas, India is producing somewhere around 913 Mtoe. But if you divide this value by the population, you will see that the energy per capita comes down to a very small number in India as compared to what is available to other developed nations like United States, Germany, Canada, Spain, United Kingdom. So it is about the energy per capita, which is more important rather than the total energy which you are indicating.

So, as we move towards becoming a developed nation, we will have to increase this number significantly so that the energy per capita can go to a number, which is somewhere near. As

the two nations, China and India are similar in population. So, we should also be nearly similar in the term of energy production.

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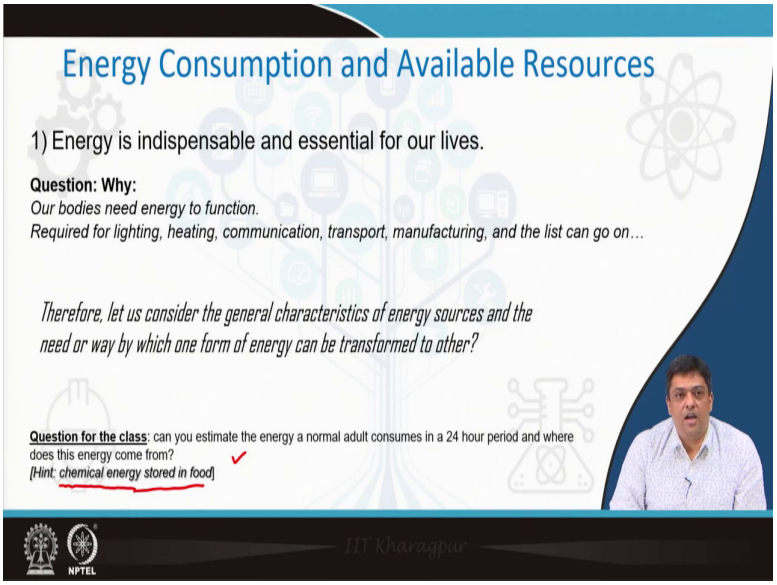

So, if we want to produce energy, we must also understand why do we need energy, how do we consume energy, and what are the available sources of energy? Let me make a statement. A statement like, energy is indispensable and essential for our lives. As I mentioned in the third slide, we will be asking questions to every statement which we will be asking questions.

So, the first question is why do we need energy for, and why is energy essential for our lives? If you look into human body, we need energy, energy for functioning. If I am talking to you, I am consuming energy, heartbeat requires energy. So, you need lot of energy for performing the human activities. In addition, if you look around, energy is required for lighting, heating, communication, transport, manufacturing, and the list can just go on, you can just go on writing one after the other where you need energy.

And because of this, it is essential that we consider the general characteristics of the energy sources and the need or way by which one form of energy can be transformed to the other. To explain this statement, let me give you a simple question, a question which is given at the bottom of this slide. Can you estimate the energy a normal adult consumes in a 24-hour period and where does this energy come from?

So, if a person gets up in the morning, until he gets, so you run a 24-hour cycle, list all the activities the person will be performing, and then calculate the amount of energy is required

for performing those activities. And where is the energy coming from, the energy? I am giving you a hint, it is coming in from the chemical energy stored in the food.

So, the chemical energy stored in the food is being converted to other forms, and then we are performing certain activities. So, I would like to ask you this question. And you can write an answer to this, it would be very simple, but interesting exercise to initiate the understanding of this course.

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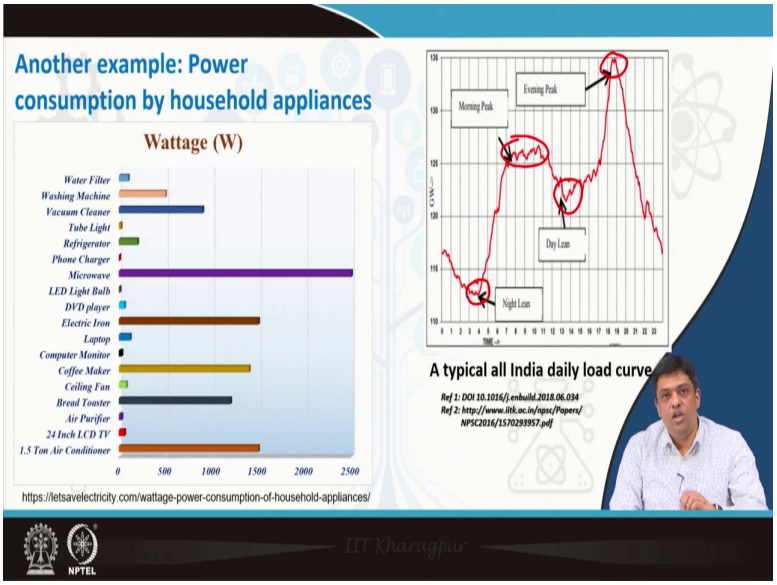

Another example, so if you look into the household, a typical household, what are the various gadgets or places where we need energy. If I take a typical house in today's world, you have water filters, you have washing machines, and the details are given on the left-hand side and the corresponding amount of power which is consumed is mentioned on the axis, which is like a bar chart on the X side. So, in watts.

On the right-hand side, you will see that there is a graph which gives you the typical load curve in India, what do I mean by that? How does the energy consumption changes in our country in a 24-hour cycle, this is what we are seeing? We will explain the importance of this as we go along. But two things, just by looking at this curve, two things become clear that you have minimas and you have maximus. If I look, so there are two points, where you see dip in the requirement and then there are points where I see an increased demand for the power or energy.

So, it is not a constant requirement in a 24 hour cycle, it varies. This is one of the major reasons why energy storage devices need to be integrated in renewable base systems and that will become clear to you bit later. But please remember, at a later point, we will discuss once again that the requirement for energy is not constant in a 24 hour cycle, it varies, you have lean patches and then you have periods where the demand suddenly rises. So, these two things you should keep in mind.

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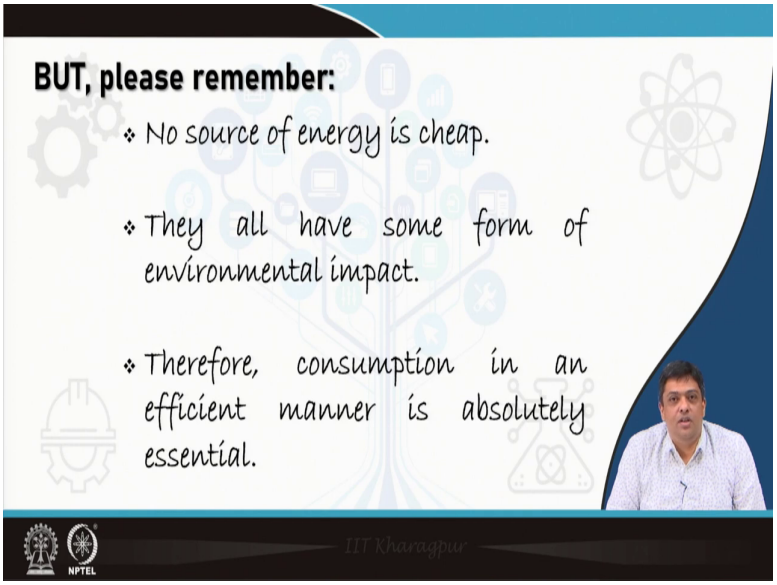

But please remember, no source of energy is cheap, they all have some form of environmental impact and therefore, the use and the consumption of these energies in an efficient manner is absolutely essential.

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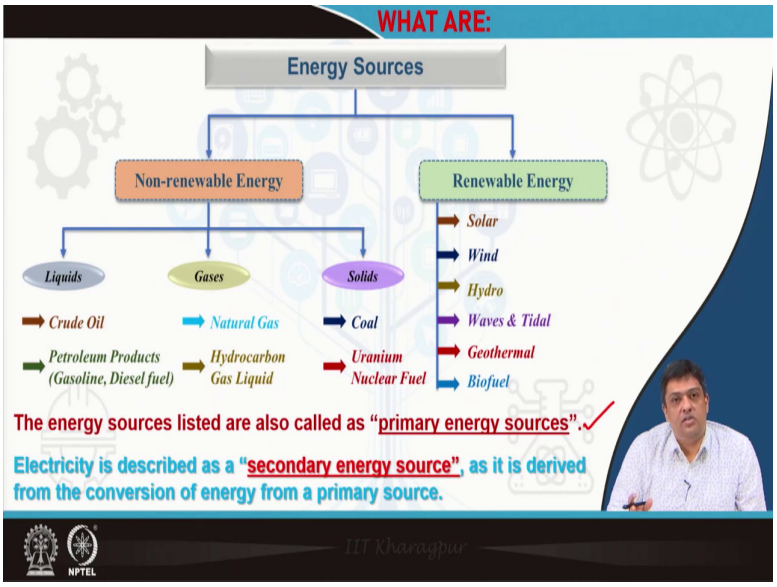

Then the next question let us ask what are these energy sources, which we are talking about. So, energy sources can be classified under two broad headings; one is non-renewable energy systems or sources, and the second is renewable energy sources. The non-renewable energy sources can be classified as liquid, gases, or solid forms of energy sources. The liquid type non-renewable energy sources are crude oil, petroleum products, gas, gaseous form of non-renewable energy sources are the natural gases.

And similarly, you can explain the non-renewable energy sources which can fall under the classification of solids are coal or uranium as nuclear fuel. Whereas, in the second classification, which are renewable energy sources, you have different sub classifications, they are solar, wind, hydro, waves and tidal, geothermal and biofuels. The energy sources which are listed on the top are also called as prime resources.

So, they are also called as primary sources. Whereas, electricity is described as a secondary energy source. As it is derived from the conversion of energy from a primary source. So, primary energy sources are the one which are used or conversion from one form of primary source to the other leads to the generation of secondary energy source. So, this is the basic difference between primary energy source and secondary energy source.

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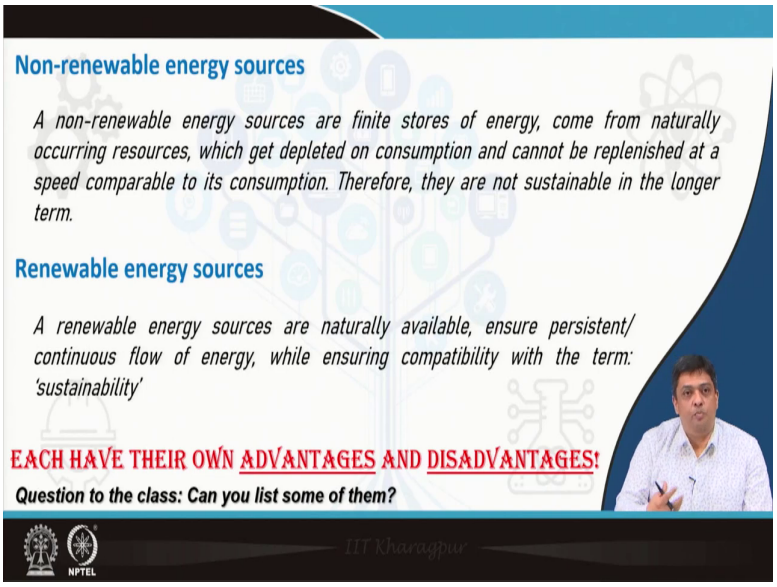

So, let us see the difference between a non-renewable energy source and a renewable energy source. A non-renewable energy source is a finite store of energy it comes naturally, it is available from naturally occurring resources, but as we use them, they get depleted and they are not sustainable in a longer term.

In comparison, the renewable energy source they are also naturally other available, but they ensure persistent or continuous flow of energy while ensuring compatibility with the term sustainability. As explained earlier, the term sustainability means that a thing which is available to us and will also remain available to the future generations.

Now, let me take an example of solar. So, if I look into the solar radiation or solar power, it is available to us and it was available to our previous generation and it will also be available to the future generations and the source itself is not getting depleted. So, the source is maintaining its availability.

In comparison, let's say fossil fuel, fossil fuel once consumed, is lost. So, once I burn the fossil fuel then I lose it and as by the continuous usage of the fossil fuel the overall store is getting depleted. Therefore, what happens that they do not remain sustainable in a longer term. But each of them have their own advantages and disadvantages.

So, second question, which I would like to post to you in today's class is, can you list some of the advantages and disadvantages of both, both non-renewable energy sources as well as renewable energy sources. I will also be mentioning them as we go along, but just to initiate

some thought-provoking ideas, I would like you to list some advantages and disadvantages of these types of energy sources.

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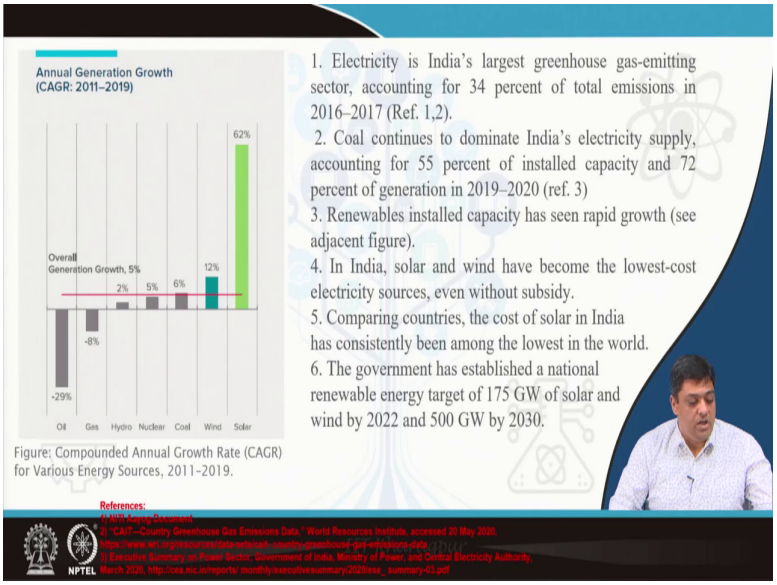

And if I look into the consumption of these two types of energy sources in India, we find that coal continues to dominate the India's electricity supply and accounts for nearly 55 percent of the installed capacity and 72 percent of generation, in the year 2019-20. I have taken this from reference number 3 mentioned in the bottom of this slide.

But, if you look into the recent trend between 2011 to 2019, there has been an increased and enhanced interest in renewables and the installed capacities of renewable systems has led to massive improvement in the solar based systems and it is being realized that in India, solar and wind are as of now, the most useful for us.

Additionally, solar and wind have become the lowest cost electricity resources, even without government subsidy. So, even if government withdraws the subsidy, these two renewable sources are becoming economically viable for us. And if I compare various developed nations or fast developing nations like India, then the cost of solar in India is still maintaining a very low level.

So, we are amongst the countries which are able to ensure that the cost of production using solar as the source is quite low. And therefore, the government has established a National Renewable Energy target of somewhere around 175 Gigawatts using solar and wind by 2022

and 500 Gigawatts by 2030. So, you will see a rapid growth in these two renewable systems in years to come.

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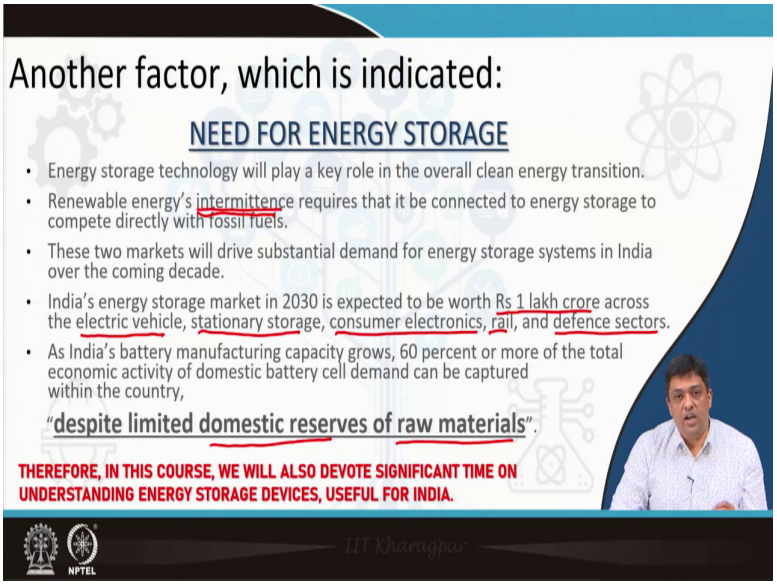

So, another factor which is indicated in the NITI Aayog document is the need for energy storage devices. These energy storage technologies will play a key role in the overall clean energy transitions. And, the renewable energies intermittence requires that it becomes, that it is connected to energy storage to compete directly with fossil fuel. This sentence introduces a very important concept and the intrinsic limitation of renewable energies.

The intrinsic limitation that the renewable energy sources can be intermittent in nature, what I mean, if I look into solar, then the sun is available during daytime and then it is not available during the night-time. Therefore, the performance of solar cell which uses solar radiation as the source will vary. So, there, there is intermittent nature in the source and therefore the performance from the system varies. To counter this intermittent nature, you need energy storage devices.

That means, these storage devices will store energy when the source is available and the system is generating energy and will supply energy to the end user when the source may be feeble, but the requirement may be quite high. And these two markets are therefore, going to drive the substantial demand for energy storage systems in India over the coming decades.

So, you will have two markets that is electric vehicles as well as the consumer market household usage of electricity which will drive the market of energy storage devices. And if

you look into the number the energy storage market of India by 2030 is expected to be quite high. And this includes all contribution from market which is based on electric vehicles or stationary storage, consumer electronics, consumer electronics like your mobile laptops, or any kind of mobile technologies, rail and defence sector.

So, there are various sectors which are going to use renewables as the primary source of energy, but they will also be using energy storage technologies. And India is rapidly moving towards building a very large manufacturing capacity and wants to develop battery cells which are fabricated within the country despite the limited domestic reserves of the raw material.

So, this is very important to understand that, if you look into lithium-ion batteries, India has practically no reserves of lithium and we depend on supply from outside world. So, India would like to move towards technologies which are not based on lithium, but other ions, such as sodium or aluminium for which the raw material is available within the country, and you would find that the performance of the energy storage systems are directly linked to the type of materials which are used or the type of materials which are fabricated.

Therefore, we will also be devoting significant time on understanding energy storage devices which are useful for India and what are the types of materials which are used in fabricating such energy storage devices.

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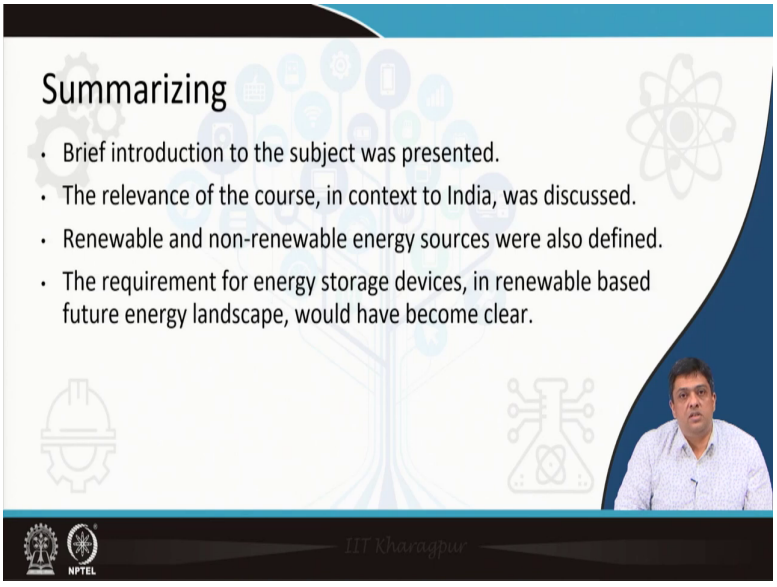

So, let me summarize what we have tried to cover in this first introduction lecture. We have tried to build and give you the introduction and the relevance of this course in context to India. I have also very briefly explained the difference between renewable and non-renewable energy sources. And towards the end, I hope, the requirement for energy storage devices in renewable based future energy landscape would have become clear to all of you.

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So, these are the references which were used to make the slides or to obtain the data, which were presented in today's lecture. And with that, I thank you for attending the course. Have a nice day. Thank you.