Energy Economics and Policy
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Week - 05
Energy Supply - Part II
Lecture - 01
Economics of Renewable Energy Supply: Setting the context

Welcome to the 5th week of the course Energy Economics and Policy. During this week we will discuss the Economics of Renewable Energy and today we will discuss a few facts in order to set the context.

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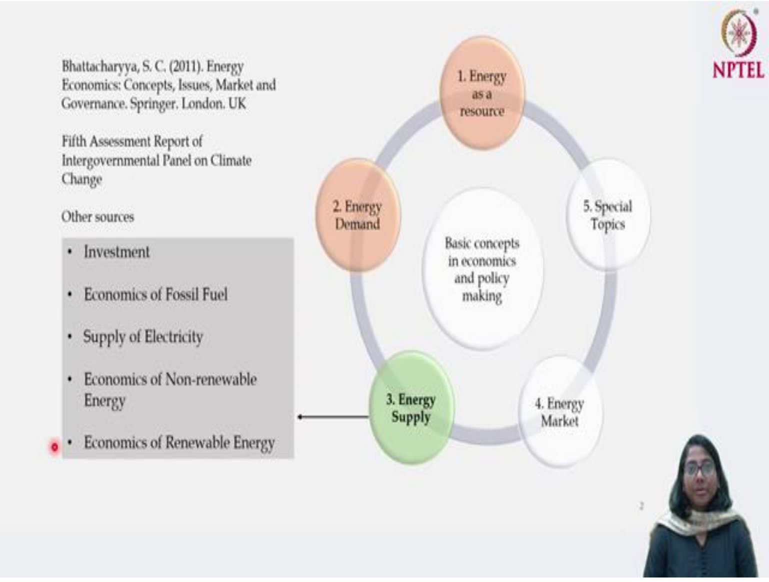

We have already covered the first four topics under module 3 and during this week we will be covering the last topic, Economics of Renewable Energy. Given here is the material that you can go through if you want more information and in depth understanding of these issues. As we move along, we will keep on providing more resources and more websites to check.

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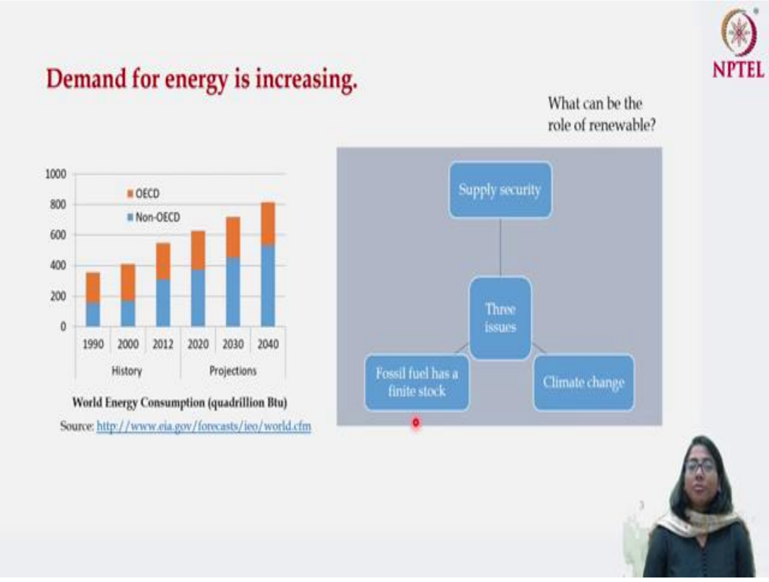

The starting point of the whole problem is that demand for energy is increasing and following is the graph which you have already come across while discussing the energy demand. The graph shows that the projected energy demand over the period of 2020-2040 is going to grow at a very high rate and at the end of 2040 the projection is that the total energy consumption is going to cross 800 quadrillion Btu.

Now, the question is where will this energy come from and what is going to be the role of renewable energy in the context of this growing demand? Here we can address three issues given the background. The first is that fossil fuel has a finite stock. Although at the current point most of this energy demand is being supported by production of energy with the help of fossil fuel. But after a point of time the stock of fossil fuel is going to go over, in that case shifting the burden from fossil fuel to non-fossil fuel and to let the technologies of renewables that is non-fossil fuel mature over a period of time is a good idea.

The second is supply security. This is connected to the fact that fossil fuel has a finite stock. Since it has a finite stock, after a point of time it's going to be depleted from major parts of the nation. The remaining stock will probably be with a couple of countries. Therefore, if the world wants to produce electricity from fossil fuel, they have to depend on a handful of countries where the fossil fuel is still available. That will cause a huge problem of supply security because whether fossil fuel will be supplied by these few countries will depend a lot on the geopolitical scenario.

This we will discuss in some future modules on energy security but I would like to take you back to the context of the 1970's where the world experienced oil price shock. A few countries had oil with them and they just did not want to supply the oil to some other countries which led to the oil price crisis and there was a shoot up of oil prices. In future as the stock of fossil fuel is going to deplete, the supply security is going to emerge as a very big issue.

The third issue which you all must be aware about is climate change. The emission that comes out from burning fossil fuel in order to produce power consists of a lot of greenhouse gases and this causes global warming leading to climate change. If the shift is towards renewable energy it has been seen that throughout the life cycle of this renewable energy production the emission of carbon dioxide or other greenhouse gases is much less as compared to what we get from the burning of fossil fuel.

Therefore, we can shift to renewables by replacing fossil fuel which can contribute in three different ways. However, it does not mean that there are no challenges associated with the shifting to renewable. There are many challenges associated with the technology, the governance structure, the policy, the acceptance of renewable energy and practical implications for example, availability of space. Many of the renewable energy such as solar or biofuel need a lot of space in order to harness that energy. There are real life challenges as well, we will try to explore all these advantages and challenges as we go on.

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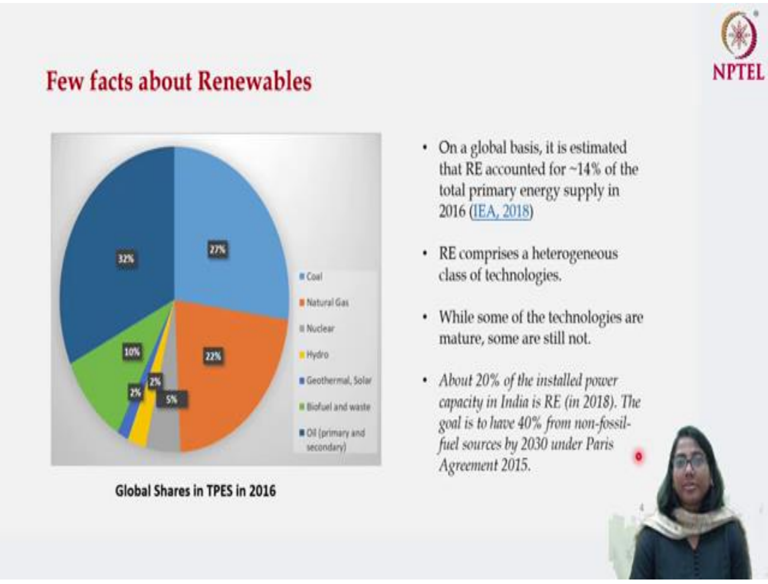

A couple of facts about the renewables. On a global scale it was estimated in 2016 that renewable energy contributes approximately 14% of total primary energy supply. If you want to revise the concept of total primary energy supply, I would request you to go back to week 1 where we discussed the energy balance table and came across the idea of total primary energy supply.

However, one point to note is that it is not the only way how total primary energy supply can be measured, there are other ways as well but basically the idea is more or less the same. The renewable account for 14% of TPES; however, renewable is not one homogenous category. If you look at the pie chart, we see that the whole system of power production or the supply of energy is actually dominated by coal which contributes 27%. Natural gas contributes 22% and both primary and secondary oil that is oil and oil products contribute 32%.

There is a 5% contribution from nuclear and a 14% contribution from renewables. The 10% is actually coming from biofuel and waste, 2% from hydro and 2% from geothermal and solar etcetera. As shown hydropower, geothermal, solar, wind etcetera is contributing only 4% of total primary energy supply in 2016. Why is this the case? This is because although we come across a lot of technological interventions and a lot of options with renewable energy, a number of them are mature and quite able to compete in a competitive market with non-renewable energy supply but most of the technologies are still to mature. The important point is that if you think about renewable energy it’s about uses of different technologies such that some technologies are in mature stage and some are not. So, harvesting those immature technologies which may play a big role in the future is one of the big policy challenges.

About 20% of installed power capacity in India is renewable in 2018. The goal is to achieve 40% electricity generation from non-fossil fuel sources by 2030 and this is the commitment that India has made under the Paris agreement which took place in 2015. If you look at the energy policy document of India, there is a lot of shifting focus in favour of renewable energy especially for solar energy.

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As we have discussed that there are multiple technologies available in order to harness the renewable energy, we are going to discuss 5 major renewable energy technologies. If you want to know more about them you can visit the 5th Assessment Report of the Intergovernmental Panel on Climate Change where they are discussing more about these technologies and some other technologies as well.

Starting with solar energy, what do solar energy technologies do? They harness the energy of solar irradiance to produce electricity using two different technologies, one is the photovoltaic technology called PV and the other is called Concentrating Solar Power (CSP). This energy is used to produce either thermal energy for further use in heating and cooling or they are used directly to meet the lighting demand.

The second one is hydropower, especially the large hydropower is a mature technology in place for a number of years. This harnesses the energy of water moving from some higher to lower elevation primarily to generate electricity. However, other than generating electricity it produces a lot of co-benefits in terms of supply of drinking water, irrigation, flood and drought control through the setup of dams and for navigation as well. Also, some of the hydro power project sites emerge as a tourist spot so there are a lot of co-benefit generated by these hydropower projects.

However, there are conflicts in terms of social costs. The interesting part is that when we talk about the cost of electricity which is being generated, we often do not take into consideration the benefits that are generated along with generation of electricity. This you can recall from the discussion on economic cost and financial cost and economic benefit and financial benefit. All these co-benefits that we are discussing are more sort of an economic benefit to a hydropower project and they will be discussed in some other context as financial benefit.

The third one is the wind energy which harnesses the kinetic energy of moving air from large wind turbines that can be off-shore or on-shore. One is inside inland and the other is not inland that is offshore. This technology is matured but wind technology has faced a lot of challenges when it comes to the question of deployment.

The challenges are not only technological or financial, in many cases the challenges are cultural as well because it changes the whole landscape. In many places especially in the context of Europe there is a large literature which shows people didn’t like wind energy as they didn’t like the presence of the wind turbines in the locality. The fourth one is geothermal energy; it utilizes the accessible thermal energy from the earth’s interior. Hydro thermal power plants and thermal applications of geothermal energy are mature technologies. There is another technology called Enhanced Geothermal System (EGS) which is in the pilot phase. A lot depends how this particular technology will mature in future in order to ensure the future of geothermal energy.

The last one that we are going to discuss is bio energy and if you recall the previous pie chart you will remember that a lot of contribution is actually coming from bio energy and waste. This can be produced from a variety of biomass including the forest, agriculture, livestock residue etcetera. You can also use organic part of the municipal solid waste, that can be used in different forms of technology including small- and large-scale boilers, the domestic pellet-based heating system etcetera. These are more common technologies and there are some other technologies which are still to mature.

The important point of discussing these renewable technologies is that, the amount of energy harnessed by large hydro power which is a matured and commercially viable technology is way more than the energy harnessed by solar power, wind energy, geothermal, bio energy taken together. It depends on how the technology that is not matured yet will mature in future and come into the force in order to harness this kind of power in a cost-effective manner. This is what we have to wait and see.

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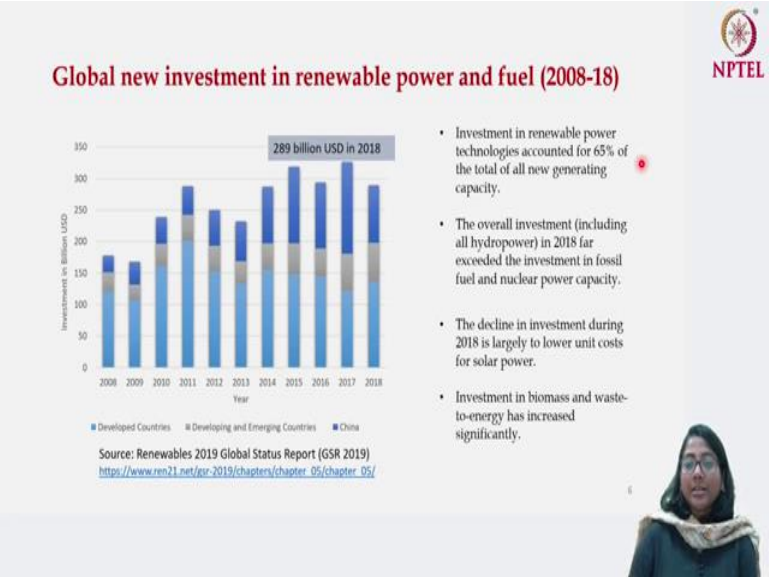

However, the good news is that the global new investment in renewable power and fuel is growing. The data from 2008-2018 shows that there is almost a steady growth in the investment in renewable power and fuel other than few fluctuations.

The other interesting fact shown in the bar diagram is that each bar consists of three parts. The bottom one, light blue part, shows investment from the developed countries, which is of course dominating. The second part shows the investment from developing and emerging countries and the top part is the investment added by China.

Initially, in 2008, 2009 and 2010 investment were largely dominated by the developed countries. Only a small portion, maybe one fourth was coming from the developing and emerging economies. As we move on in time a large part is now actually coming from developing countries with a major contribution made by China. China's role has become really important in case of new investment in the renewable energy projects. Investment in renewable power technology accounted for 65% of the total new generating capacity and has been growing at a large scale.

The second interesting fact is that the overall investment including hydropower in 2018 far exceeded the investment in fossil fuel and nuclear power capacity. The third point is that there has been decline in investment and some departure from. The investment has declined from 2017-2018 by around 20-22%. It might seem that there is a decline in investment but this is due to a good reason. The reason is that the unit cost of solar power has come down and therefore it requires less investment. The other message that we can take from here is that it is good that we are getting an increasing trend of investment but it is also good to observe that the cost of these technologies is coming down.

As a result, the requirement for investment will come down in future or the same amount of investment can actually harness a lot more amount of renewable energy. The final that we have already discussed is that biomass has a major role to play in the context of renewable energy and the investment in biomass and waste to energy has increased significantly over the years.

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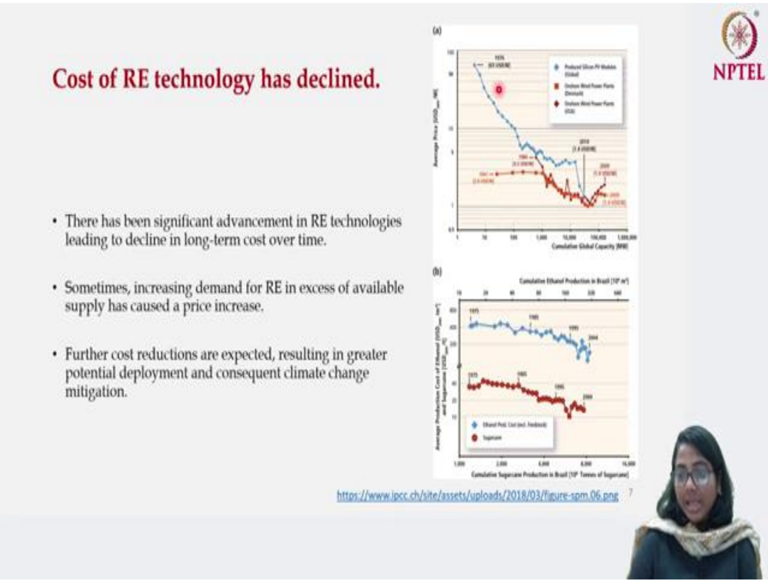

Given that the cost of renewable energy is declining when the investment is increasing, there are two very interesting diagrams taken from the 5th Assessment Report of the Intergovernmental Panel on Climate Change. Panel ‘a’ shows a blue line which is actually plotting produced silicon PV modules at a global scale and the average price of these silicon PV modules. The cumulative global capacity has increased over the years and the average price has declined or you can interpret it in the other way. As the average price declines the cumulative global capacity has actually increased.

In 1976, the price was 65 USD per watt of power generation and it has come down little over 1 USD per Watt whereas the capacity has increased a lot. There is a significant decline in the produced silicon PV module average price measured in 2005 units per watt. The same is actually happening for the onshore wind power plant. The two orange lines capture the increased capacity of these offshore wind power plants in Denmark. One is for Denmark and the other is for the USA, this has also come down. There has been a slight increase in prices in the last few years but the general trend is actually decrease in price. Here you can see that not only for the wind and solar power but the price is actually declining for the bio fuel as well.

The cumulative sugarcane production in Brazil has been plotted and you see the average production cost of ethanol. The trend is not as significant as you see in case of solar or wind but it shows a declining trend. There is a significant advancement in the RE technologies leading to decline in long term cost over time.

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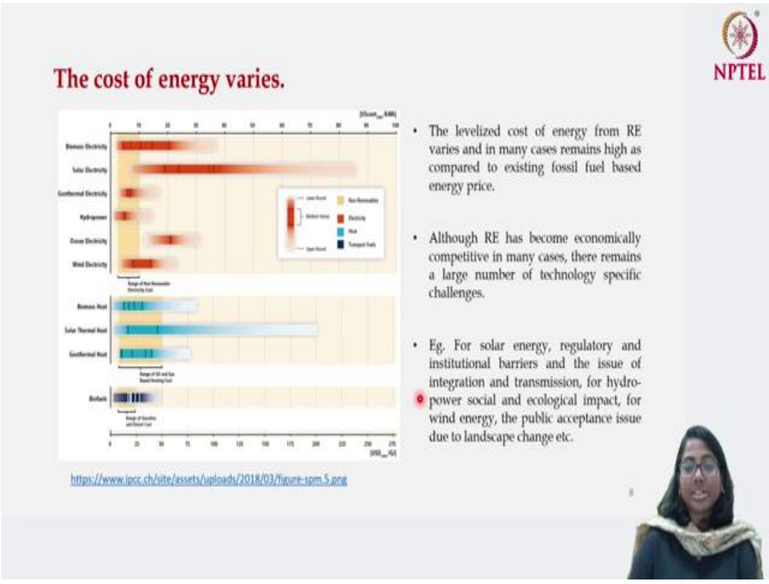

However, when we say that the cost is declining, one issue with renewables is that since there are various technologies available, the cost of energy production also varies a lot. In the diagram there are different technology options on the vertical axis that are available for energy production and the cost of production USD, in 2005, constant price per gigajoule.

For example, take solar electricity which gives the highest variation. There is a range of options available and in some cases the production of electricity from solar energy can be very low, it can be less than 10 cents per kilowatt hour. It all depends on how the technology matures and how the cost of production of power through these technologies actually come down. This is the important part of generation of power with the help of renewable energy. Since there is a lot of variation the levelized cost of energy from RE from many cases actually remains high as compared to the conventional power generation system.

For example, if you think about the technology of solar electricity or solar thermal heating, of course, the price or the cost is going to be much higher than the conventional way of producing the power. Therefore, we can say that although renewable energy has become economically competitive, in many cases there remains a large number of deployment challenges when we talk about the technologies which are not matured yet.

If you take the example of solar there are various factors why these technologies are facing the challenges or difficulties in terms of maturity. If you think about solar power, the regulatory and institutional barriers at the issue of integration and transmission are the major issues related to solar power. As for hydropower, the technology is already matured but there is a lot of social and ecological impact which is discussed when the implementation of hydropower projects has to take place.

For wind energy there is always a public acceptance issue. This is something we already have discussed. It is not only the financial cost that matters, there are a lot of other economic, social or policy related barriers that are there in order to create some sort of a hindrance in the implementation of renewable energy and it is not very wise to ignore these hindrances because sometimes they are very logical. Therefore, it is very important to pay good attention to those hindrances and see how these challenges can be overcome.

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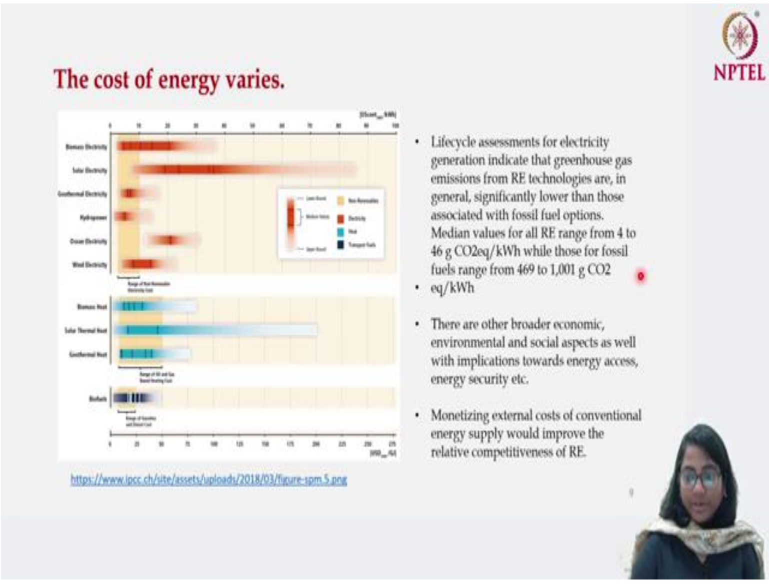

As we have said, the generation of electricity from renewable sources most of the time is higher than the cost of production of electricity from conventional sources. However, when we talk about the cost or about the benefit that we derived from renewable energy oftentimes we do not take into consideration all the economic benefits that are being generated by renewable energy.

The life cycle assessment for electricity generation indicates that greenhouse gas emission from renewable energy technologies are in general significantly much lower than those associated with fossil fuel options. Coming to the numbers, the median value for all renewable energy will range from 4 to 46 gram of carbon dioxide equivalent per kiloWatt hour of electricity generated while the same for fossil fuel will range from 649 to almost 1000 gram of carbon dioxide equivalent per kiloWatt hour.

The interesting thing is that even if you take the highest range of the median value which is 46 gram of CO_2 equivalent per kiloWatt hour and if you take the lowest bound of the CO_2 emission from the non-renewable energy this is 469, this 46 is actually 10 times lower than the 469. The greenhouse gas emissions from renewable resources are much less as compared to the non-renewable energy.

However, sometimes it becomes difficult to capture the benefit in terms of constructing the cost that is associated with the non-renewable sources. It is so because there is an avoided emission. You are avoiding producing something which is bad; however, there is no market or there is no matured market where you can do some sort of a carbon trading. But a vast global traditional market is yet to emerge for CO_2, the buy and sell of CO_2 credits which can encourage the incorporation of this kind of benefit where the total benefit of renewable is being calculated.

However, this is not the only issue to look at but there are other broader economic, environmental and social aspects which generate a lot of benefit when there comes the question of renewable energy deployment and as we are thinking about the cost-benefit analysis in the economic terms it is very important that all these environmental, social and economic costs and benefits are taken into account to compare the renewable and the non-renewable.

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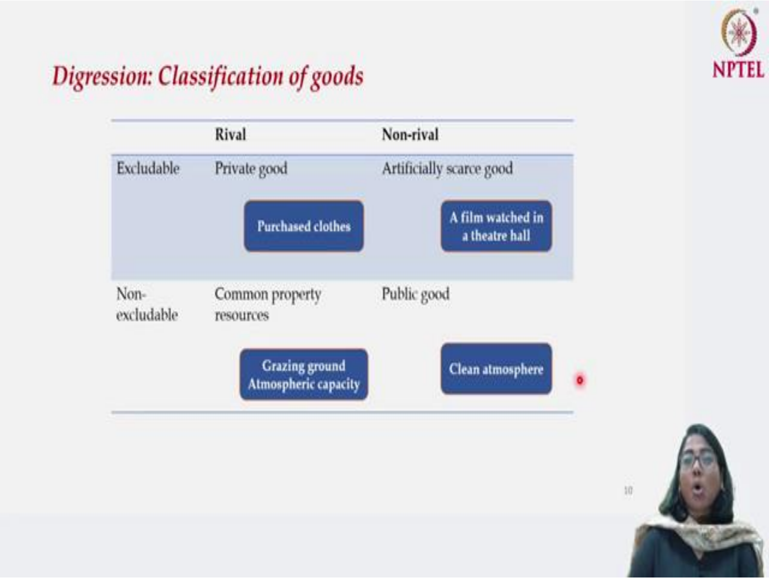

Finally, before I end this section, I would like to draw your attention to the classification of goods. These are the concepts that we are going to use in the next slides or next lectures and here it might seem a little out of the place but you will be able to connect the concepts as we go along.

In economics the goods are classified in four different manners. These four different kinds of goods and services are the private good, common property resources, artificially scarce goods and the public good and what we are most interested in is the concept of public good.

These four types of categories are derived based on two properties of these goods and services; one is the property of excludability and the other is the property of rivalry. If you think about a purchased cloth that you have paid a price and have bought from the market is a typical example of a private good. This is excludable because if you don't have the money then you don't go and buy it and therefore, you can exclude those who do not have the purchasing power from the use of this particular goods and services.

Why are they called rivals? They are rivals because if you have purchased and have been using the particular cloth then the same cannot be used by somebody else. Private goods are characterized by excludability as well as rivalry whereas public good is just the opposite. This is characterized by non-excludability and non-rivalry.

Another example could be of a non-crowded road. If you walk on a non-crowded road then it is non-excludable because you are not excluding anybody else from using that road. Somebody else can also come and join the walk with you and secondary this is non-rival because this is sort of not a crowded road. The benefit or the joy that I am deriving out of walking on that road will actually be gained by somebody else as well, so this is non-excludable and non-rival.

The problem with non-excludability and non-rivalry is as follows, because I am not excluding anybody and because I am not creating any rivalry, nobody is willing to pay for this kind of a public good, so a clean atmosphere is another example. We all derive benefits from a clean atmosphere. If I derived some benefit it does not hamper the other person from entering the same use pattern and it is non-rival in nature.

As a result, a clean atmosphere is more like a public good, as we emit more greenhouse gases or local pollutants, we actually emit it in the clean air. If you think a clean atmosphere is a public good then polluted atmosphere is a public bad and given the property of a public good nobody is willing to invest or willing to pay for something which is non-rival and non-excludable. Therefore, investment in public goods is a big challenge and it rarely comes from the private investors.

Therefore, we see things like roads, big power plants are all built by the government in many of the cases. The other two examples, this is non-rival but excludable are called artificially scarce goods. A film watched in the theater hall can be an example of that and the final one is a grazing ground or the atmospheric capacity which are rival but non-excludable. Atmospheric capacity is not excludable but rival because as you keep on adding more CO_2 equivalent in the atmosphere the capacity of the atmosphere to absorb more and more CO_2 is going to be reduced.

However, in the discussion we will come back to the concept of private good and public good as we go on and we will see how renewable energy has the properties of public good and therefore, there is additional policy intervention which is needed in order to promote renewable energy in the context of power generation or the sustainable use of energy.

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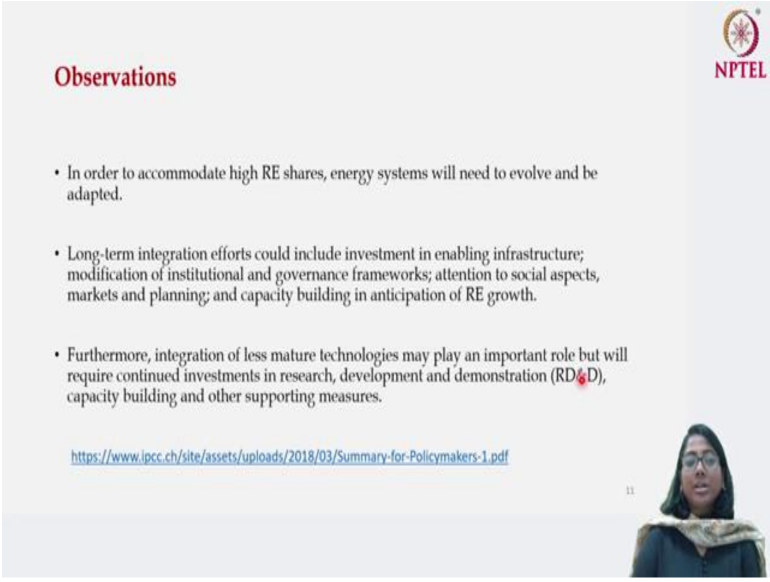

Coming to the end, following are the observations that we are going to make. In order to accommodate the high renewable energy share, the energy system will need to evolve and be adapted. Long term integration efforts could include investment in enabling infrastructure, this is important because they have public good characteristics, modification of institutional and governance framework, attention to social aspects, markets and planning and capacity building in anticipation of renewable energy growth. Furthermore, the integration of less mature technologies may play a very important role but we will require continued investment in research development and demonstration, capacity building and other supporting measures. If you want to read more on this chapter, I would urge you to go and visit the given website and read the summary for policymakers.

Thank you.