**Energy Resources, Economics and Environment**
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**Lecture 3 P2**
Energy Inequality

So, we saw in the last class the link between Energy and Quality of Life, we talked about the Human Development Indicator. Today we are going to look at the inequality, how to measure inequality and what do we understand, what is energy inequality?

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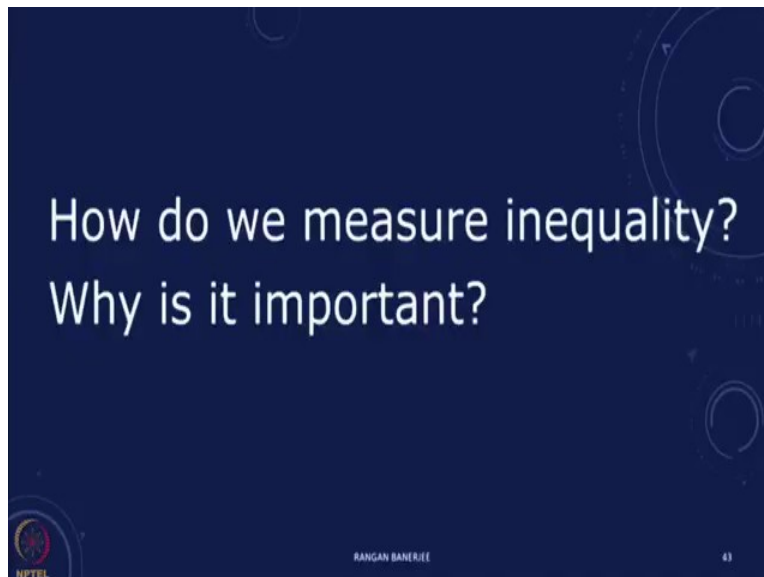
So, the two questions that we need to ask are how do we measure inequality? Why is it important? And any society or any development that we have, we would like to see that the benefits of that development go uniformly as far as possible to the entire population. And if you have a society which has more inequality, then of course, that is not necessarily from a long term that is not necessarily sustainable.

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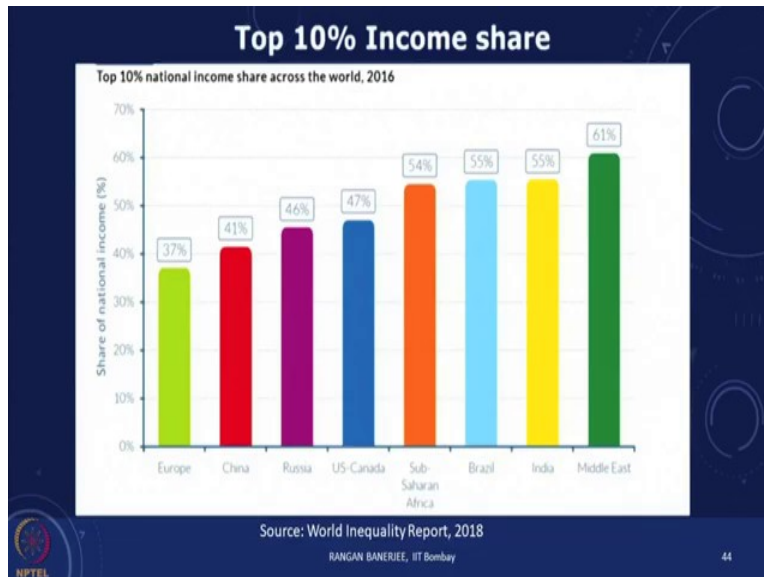
So, if you look around us, you will find that in general inequality we talk about inequality in terms of inequality of income. So, for instance if you see, if you look at this is from an inequality report, you will find that the top 10% of the population, what percentage of the income do they own, and you will find that, in India top 10% accounts for about 55% of the total income of the GNP. And similarly, you find Europe is relatively less unequal the because the top 10% owns about 37%.

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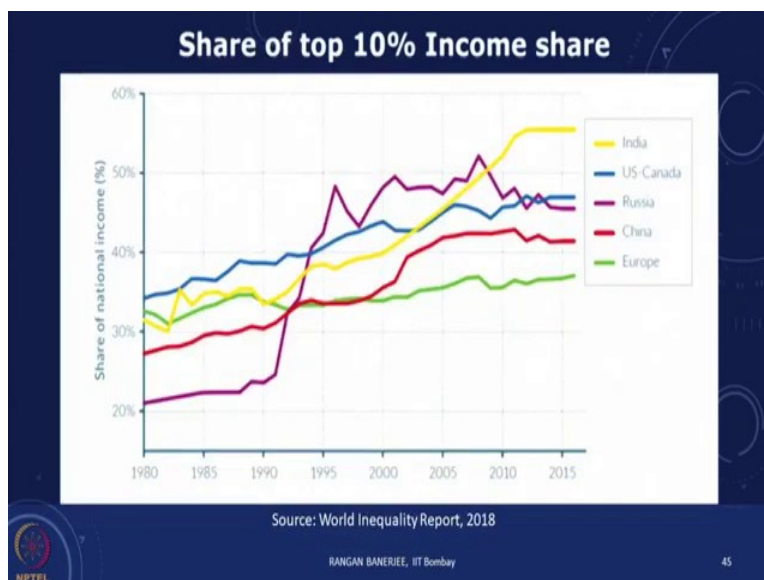
So, this gives you one possible way to look at inequality, see how much the top 10% own in terms of the income, we may also look at how the share has been changing over a period of time. So, if you look at this data, this plot shows you over a period of time from 1980 onwards, how these numbers are changing, and you will find that in, in most of the cases, the top 10 %, the share of their income has actually been increasing at a faster rate than the rest of it.

So, that means that the rich are getting richer and of course, this means, in many cases that the inequality has sort of increased and you can see in the Indian case if you look at this plot, you can see how this has been going up and then it is sort of plateaued at this point this is the kind of shape.

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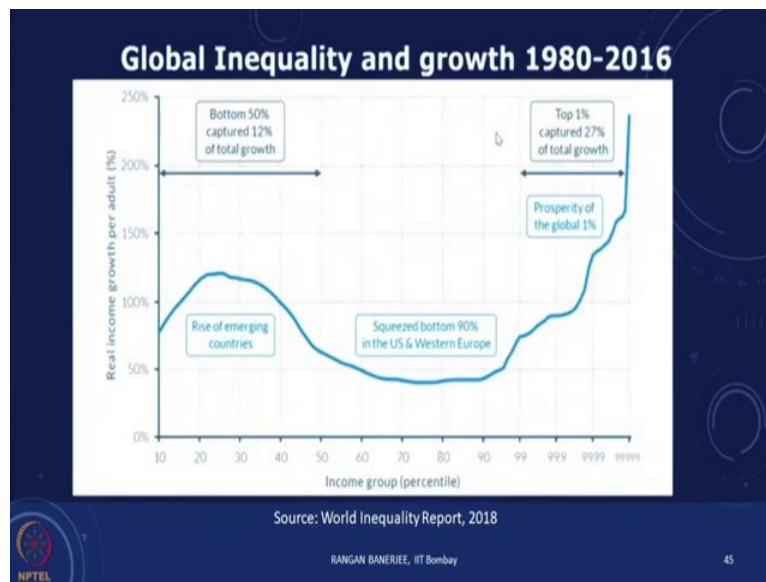
If you look at in this is, again from the inequality report, you find that, if you look at the total inequality and the income growth in terms of the different income groups, you find that the richest have been growing at the fastest rate. And so it means that of course, this is not sort of surprising, but it is quite striking in terms of the top 1% captured top 1% captured 27 % of the total growth, if you look at from 1980 to 2016.

So, this is in terms of inequality, if we want to measure this, and we would like to look at inequality in income, we would also like to look at what is the inequality in electricity use

or energy use. So, one of the matrix that we can do is we can actually take the entire population and arrange the population in terms of lowest to highest. So, if we talk in terms of income, we take the lowest x% lowest 1%, then 2%, cumulatively, how much of the population if you take the lowest 10%, how much of the income does the lowest 10% have, and so on.

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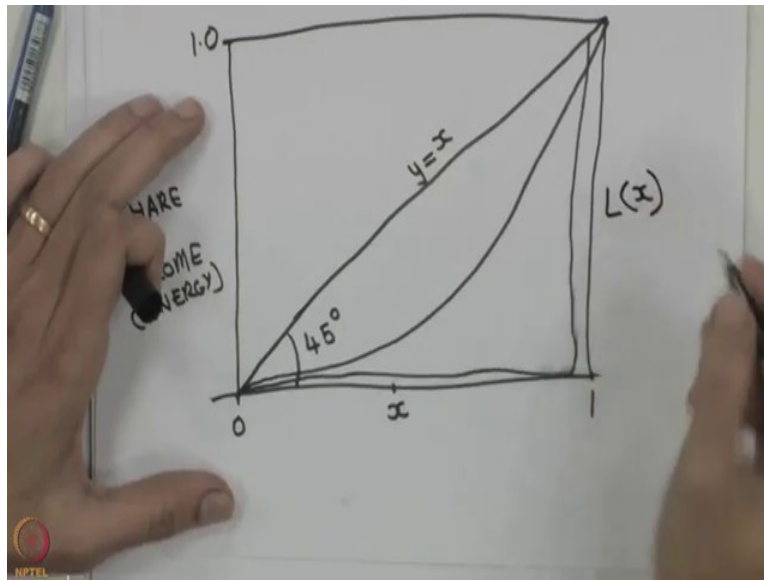
So, we have a plot and that plot is called the Lorenz Curve on the x axis, go to 0 to 1, or to 100 % and on the y axis also go to 0 to 1. The x axis shows the percentage, cumulative percentage, the lowest x percent, lowest percent, and the y axis shows the cumulative share, cumulative share of income, energy whatever we are income or if we want to plot energy and so, if we make this here.

Now if we had a real, if we had equality, complete equality, if we take any point here as x, the minimum x% of, if you take the fraction x, x going from 0 to 1, and we want to know what percentage of the income, if you had a complete equality, then the 5, if you take 5 % of the population, it would account for 5 % of the income. If you take 20 %, it would account for 20 %.

So, the line that we would have would be y is equal to x, this is where you have a complete, it is a 45° line and this is when you have complete equality. On the other hand,

if we had a set of different individuals, where everyone had 0 income, and only one individual had all the income, then you would have a curve, which would go something like this, and then go here, in actual practice, we would have something like this and so, this deviation that we have from the 45° line shows us the amount of inequality in the system.
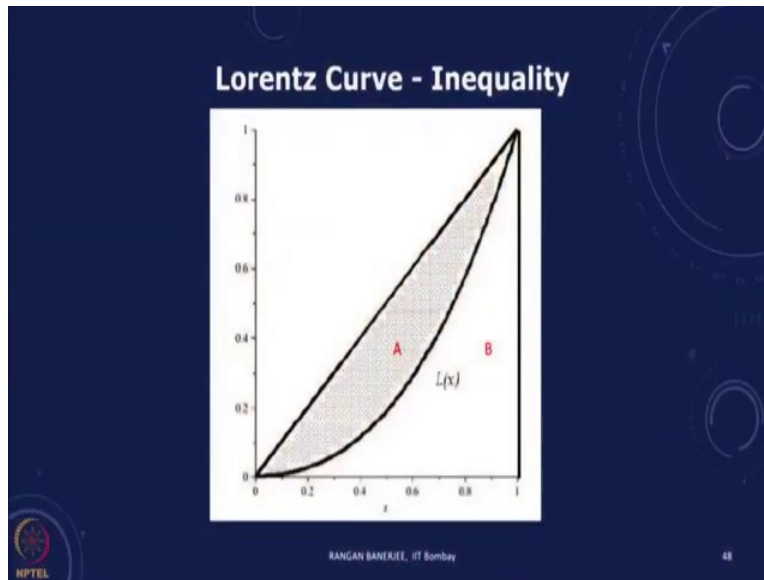
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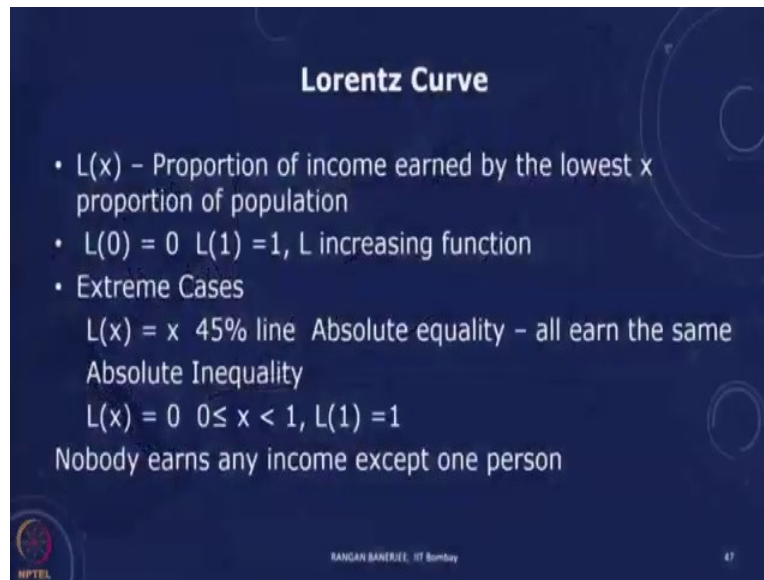
And so, this curve that we have is called, this is called the Lorenz Curve and Lorenz Curve if we see, Lx is the proportion of the income earned by the lowest x proportion of the population. So, obviously by definition L0 will be 0, 0 percentage of the population will have 0 percentage of the income and L1 means 100 percent of the population will have 100 percent of the income.

And since by definition this is a cumulative increase and the cumulative amount, this will be an increasing function. The extreme case is where Lx is equal to x, this is complete, absolute equality, all earn the same and absolute inequality is where Lx is equal to 0, for 0 less than equal to x less than 1 and that one individual earns the all the income.

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So, in between this is what you will have the curve, and this is how the curve would look. So, in this what we have is we define a coefficient called the Gini coefficient.

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$$GINI\ COEFFICIENT = \frac{A}{A+B}$$

$0 \le G \le 1$

And the Gini coefficient is defined as, the ratio of these areas, the area A divided by A plus B. So, as you can see, this Gini coefficient will be between 0 and 1 with 0 representing absolute equality. And 1 representing absolute inequality, anything in between the lower the Gini coefficient, the more equal is the society.

And so let us look at some of these numbers, how do we compute this?

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Gini Co-efficient

- Gini coefficient = A/ (A+B)
- A+ B = 0.5
- Gini coefficient = 2 A

$$= 2\int (x - L(x))dx$$
$$= 1-2B = 1- 2 \int L(x)dx$$

$$G_c = 1 - \sum_i (Y_{i+1} + Y_i)(X_{i+1} - X_i)$$

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$$GINI\ COEFFICIENT = \frac{A}{A+B}$$

$0 \le G \le 1$

$$G = 2\int \left(x - L(x)\right)d_x$$

If we use we can approximate it if they are points, and we use the trapezoidal rule, you can also show very easily that this is equal to if you have points Xi and Yi, we can write this as the area in this form. And so, given a set of data, you can calculate what is the Gini coefficient.

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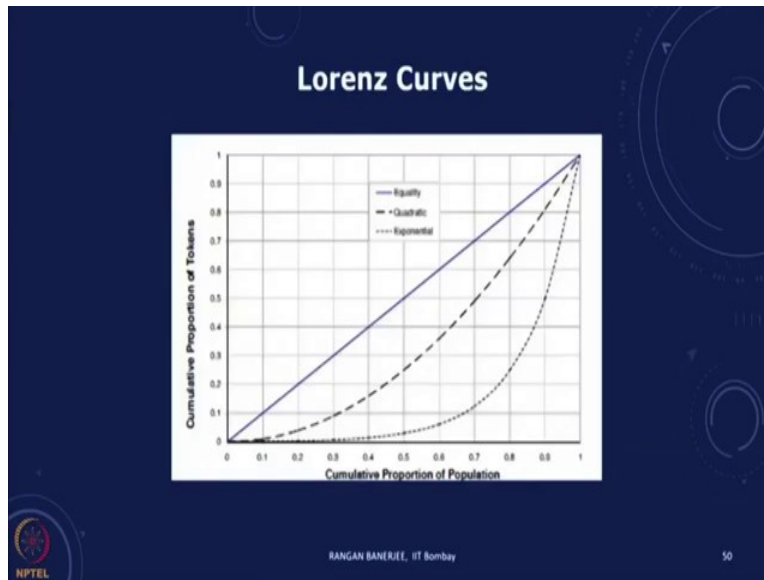
Now, just to show you some of the Lorenz curves, and you can see that the kind of different cumulative proportion of the, you can see that these are different, obviously, if you compare this curve with this, you will find that this one shows more inequality as compared to this, this will have a higher value of the Gini coefficient.

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We have plots and you can, if you just Google you will find maps which will show you different kinds of Gini coefficient for different countries. And so of course, some regions are have relatively more equality. For instance, if you look at Europe and if you look at the Scandinavian countries, and then there are other regions which are relatively more in unequal.

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So, just to give you an example, if you take this data this is from a paper for the US electricity, US household electricity consumption and this gives you the cumulative proportion of population and the cumulative proportion of the electricity consumption, one can take this plot, one can take this and plot it and draw the Lorenz curve and you can also from this get the Gini coefficient for this.

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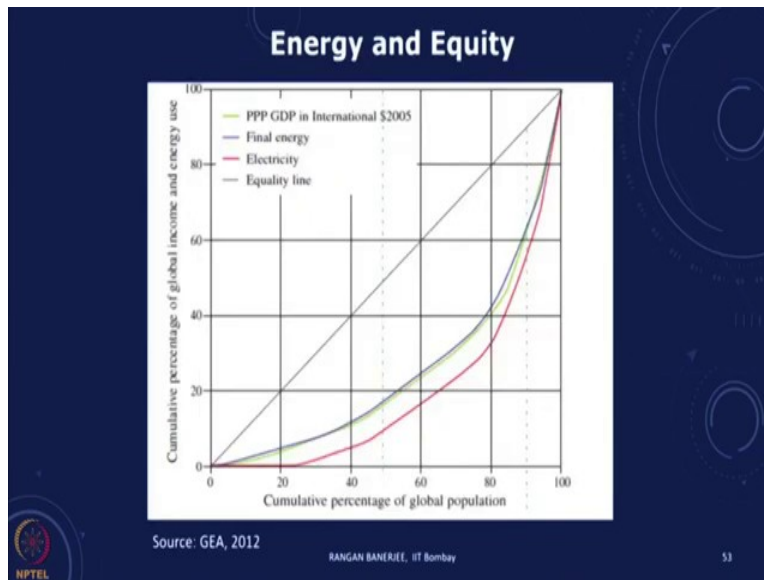
If you look at for the world, this was done in the global energy assessment, and you can see that the final energy and the electricity use you can see that there it is a fairly significant inequality. So, for instance, if you look at from this side, if you look at the poorest 10 %, if you look at the richest 10 %, you will find that the richest 10 % consume more than 40 % of the world's electricity and the final energy while if you look at the poorest 50%, you will find that the poorest 50% consume less than 10% of the total cumulative energy.

So, when we talk in terms of the overall energy scenario, there is a very significant inequality and distribution in terms of the access to energy in terms of the electricity and as we develop these inequalities, the plan is to try and reduce these inequalities.

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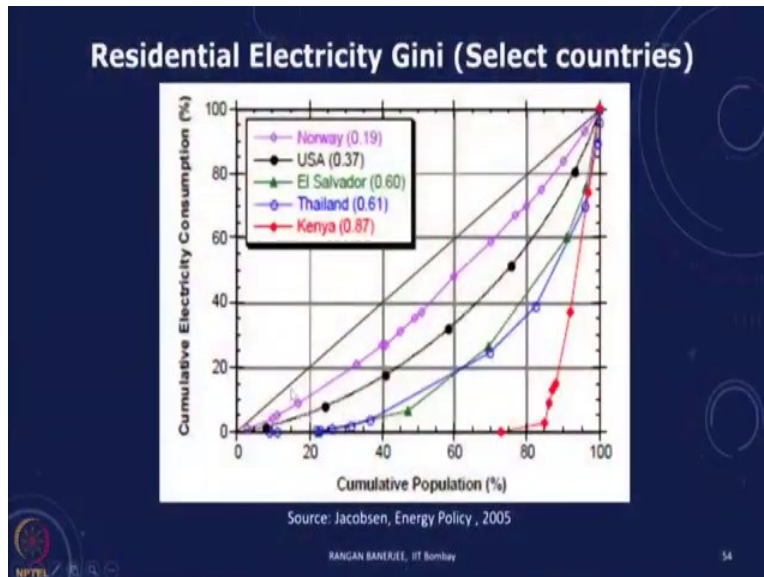
So, for instance now, this is from a paper by Jacobsen in Energy Policy, and you can see that the electricity, cumulative electricity consumption, residential electricity consumption, you will find that relatively if you see Norway as Gini Coefficient of 0.19, much more equal, then when you see Kenya, large proportions do not have access to electricity, Gini coefficient is 0.87, and it is only this which is, and similar kinds of things you can see.

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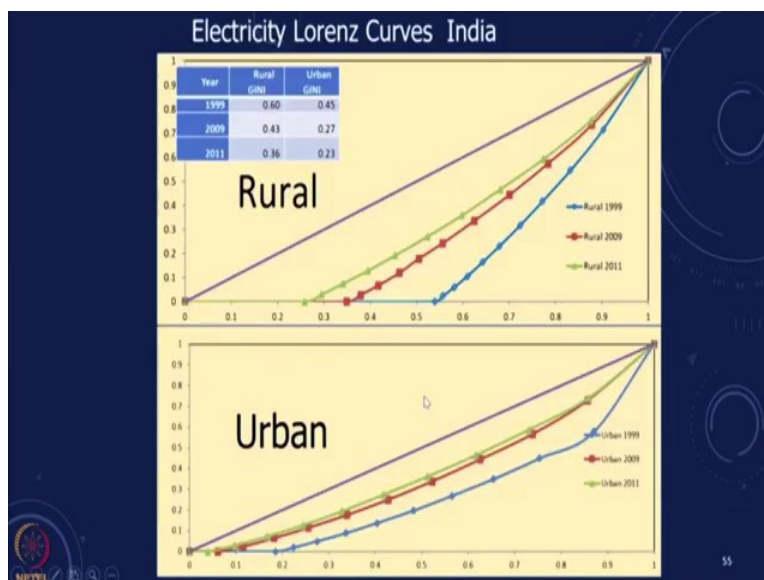
We had developed similar kinds of using the data from the NSSO, we try to develop Lorenz curves for India and you can see that over a period of time, the inequality in terms of electricity use has been declining. And this has been due to our efforts in terms of providing access and providing electricity and often providing subsidized electricity for low income users.

And you will see that in the case of urban, it is even better in terms of the Lorenz curves and so this shows you the way in which we can map the inequality in terms of the Lorenz curves and from this, we can then calculate what are the Gini coefficient.
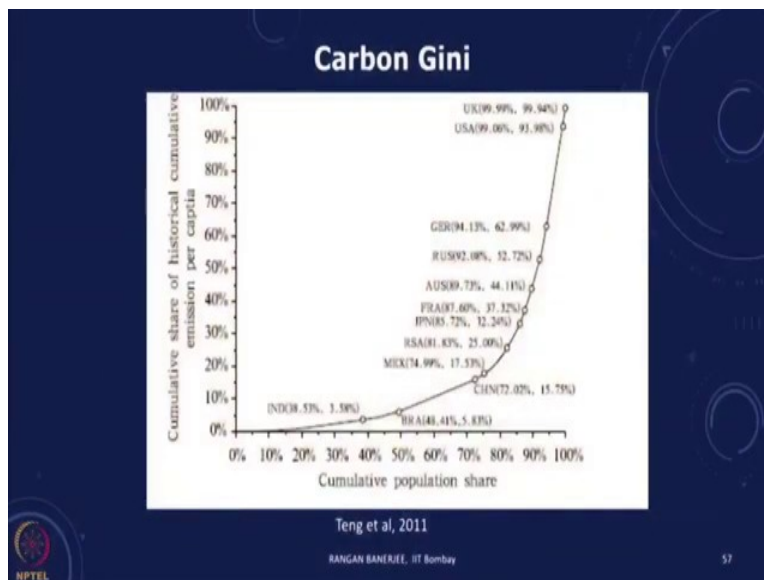
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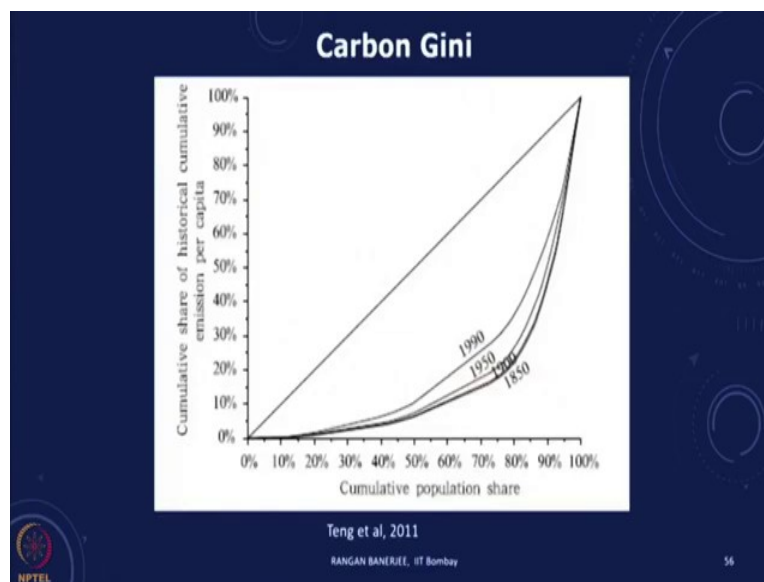
And there are papers where the overall inequality in the carbon has been also mapped and this is called the Carbon Gini. In doing this in this paper in Teng et al, they have actually taken not just in a particular year, but they have taken the cumulative share of the historical emissions.

And you can see very clearly that the emission trajectory is such that it is the richest 10, 15% which has actually been contributing for a significant proportion of the cumulative CO_2 emissions, of course, please remember in all of these calculations, we take every country as an average, there is an inequality within the country.

But these inequalities, when we talk in terms of an overall problem, in terms of Co2 emission reduction, and we are trying to get the entire world to come to some agreement, these are the issues which come in when we look at how to get an agreement, how to reduce the CO_2 emissions, and to have.
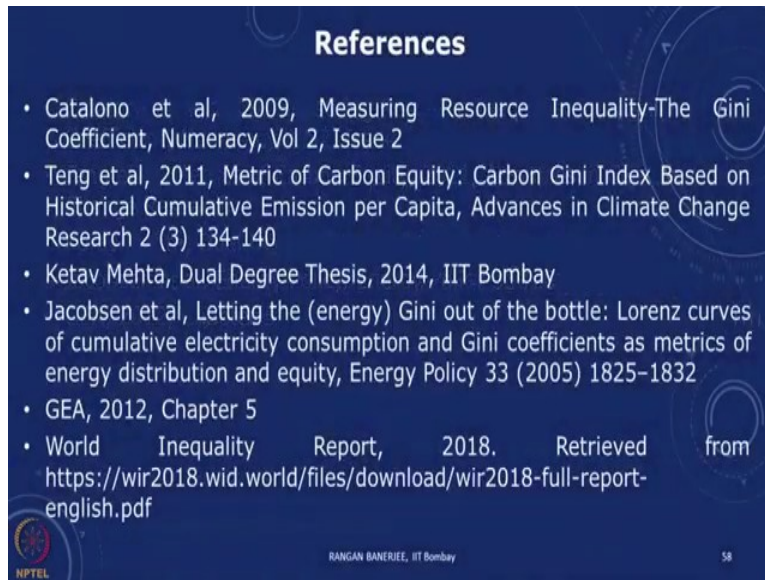
And so that is why we have gone in for instead of having a mandatory sort of a emission, every country has come up with a voluntary declaration of what they can do and that is how we have made an agreement in Paris and we are moving forward with that.

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These are again different kinds of countries on that Carbon Gini, and this gives you some kind of.

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So, these are some of the references where you can find more details, what we have done today is we have looked at the metrics for measuring equality or inequality, we talked about the Lorenz curve, and we also looked at the Gini coefficient, in the tutorial we will give you some examples of equations and how you can make some calculations, so that you can calculate the Gini coefficient in terms of income in terms of energy.

And this is something which we can use when we talk in terms of different development strategies and decide on what kind of energy requirements are required to remove the inequalities.