Energy Resources, Economics and Enviorment
Professor Rangan Banerjee
Department of Energy Science and Engineering
Indian Institute of Technology Bombay
Lecture – 15 P2
Revision paper – 1 (Part 3)

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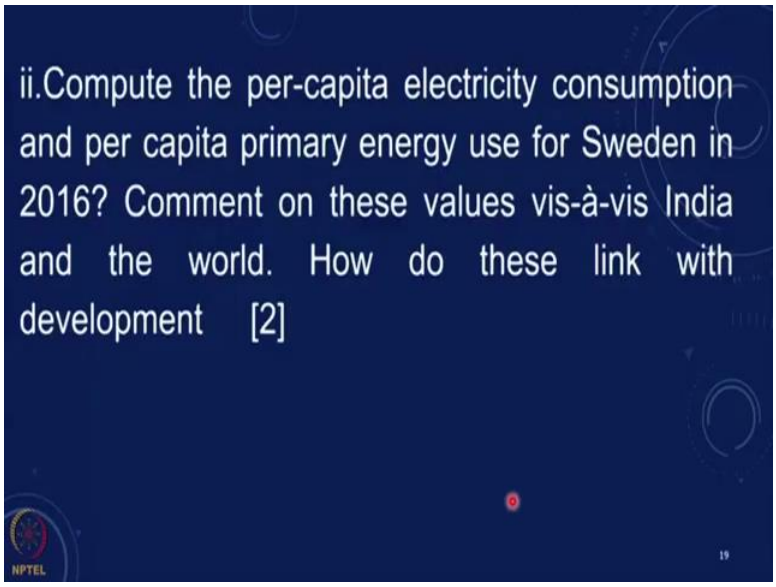

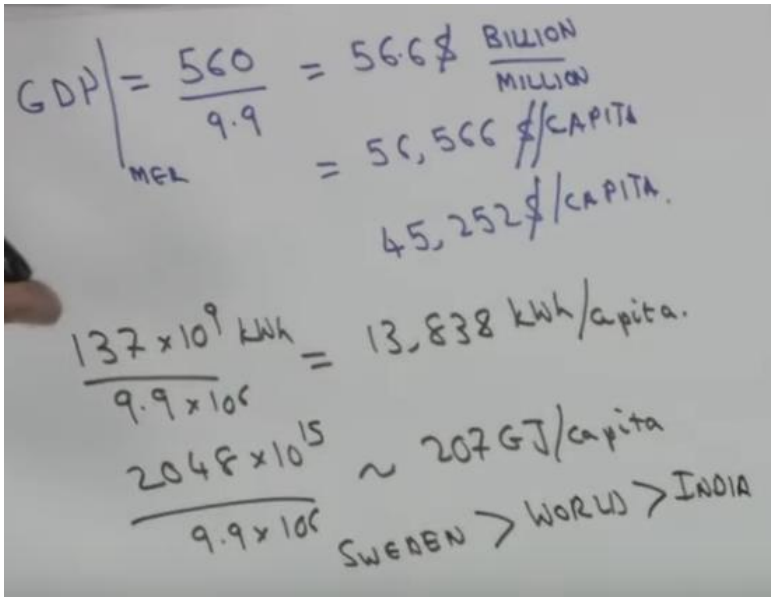

The next part of the question is compute the per capita electricity consumption and per capita primary energy use for Sweden in 2016. This is simple, this is just divide these numbers and you get, just take the total population divided by the total electricity used, kilowatt hour, divided by the population and you get 13,838 kWh/capita. Primary energy if we again we divide 2048 into 10 raised to 15 by 9.9 into 10 raised to 6, turns out to be 207 GJ/capita

Now we can compare it with the primary energy per capita for India and the world and you can see that the primary energy is supply, the per capita for Sweden is greater than that of the world average and greater than that of India, which is as we expected, but we have been able to quantify it. So, then the question is comment on these values, how do these link with development.

But typically what happens is that, with a higher level of income, you would have a higher requirement of electricity use and you can see that very clearly that in the Indian context the energy use and the electricity use is significantly lower than that for Sweden.

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Table 3. Sweden Electricity sector 2016

	Hydro	Nuclear	Wind	Solar	Total (including thermal)
Installed capacity(MW)	16181	9075	6520	175	40,125
Generation(TWh)	61.7	60.5	15.5	No data	152.3

(Source: https://www.energimyndigheten.se/en/facts-and-figures/statistics/)

We have also the next table shows us the Sweden electricity sector mix in hydro, nuclear, wind and solar and the generation. So, you we can see very clearly that in this particular case, there is a significant amount of then the total including the thermal if you look at it the installed capacity of hydro is quite significant. And we can see that hydro and wind together is a significant proportion of the total.

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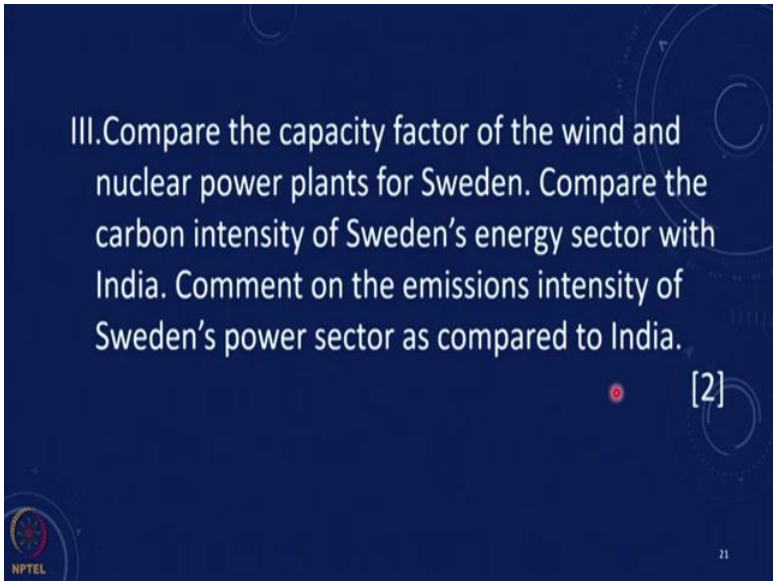

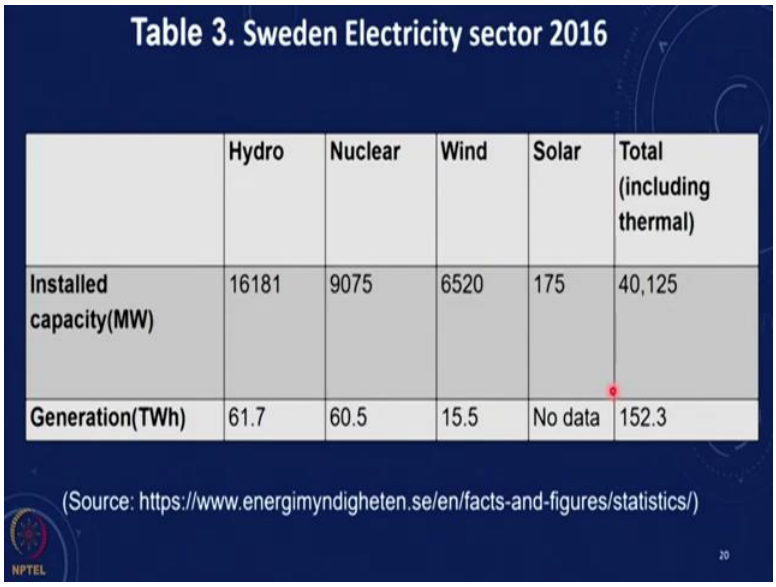

So, we should then the question asked is compare the capacity factor of the wind and nuclear plants for Sweden. So, this is fairly straightforward, because we have the installed capacity and the generation and all that we need to do is that we need to find out the capacity factor.

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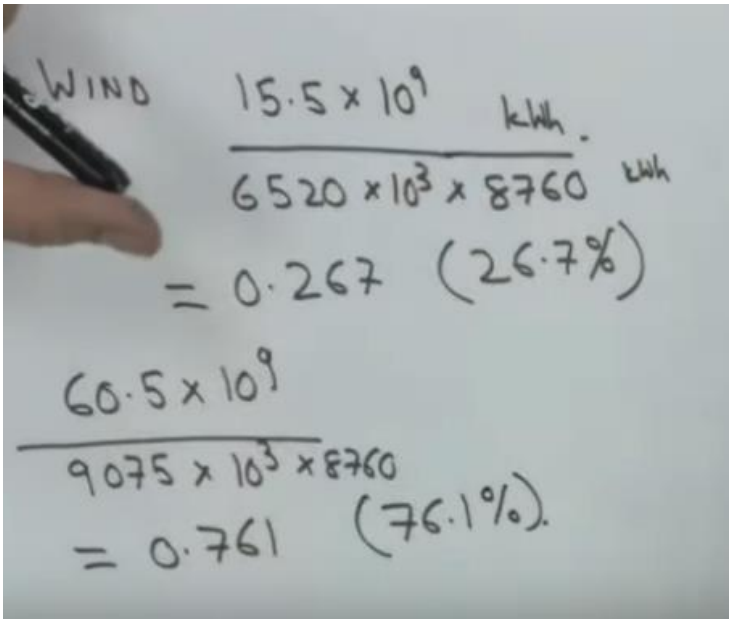

So, in the case of wind the generation is 15 point, if you see 15.5 terawatt hours, that is 15.5 into terawatt is 10 raised to 12 watt hours and if you want to make it in kilowatt hours, this will be 10 raised to 9 kilowatt hours divided by let us look at the installed capacity of wind, installed capacity of wind is 6520 megawatt which is into 10 raised to 3 kilowatt and into the total number of hours is 24 into 365 or 8760. This is the maximum generation possible if all the wind capacity is operating continuously at its rated value.

So, this will be also in kilowatt hours, this becomes a factor which is the capacity factor. You can calculate this and you will find that this turns out to be 0.267. 26.7 %, it is a fairly high, for wind it is a fairly high capacity, the Indian wind regime capacity factors are much lower. It is like 14, 15 % on an average. But also remember that this is going to be lower than that, which is there for the base load coal or thermal plants. We will also see that it is actually going to be lower than the nuclear.

Let us look at the nuclear same way. Let us calculate the nuclear. In the case of nuclear we are told that it is 60.5. So, we can do in the same fashion and nuclear is 9075 into 10 raised to 3 into 8760. Calculate this if 0.761, 76.1 %.

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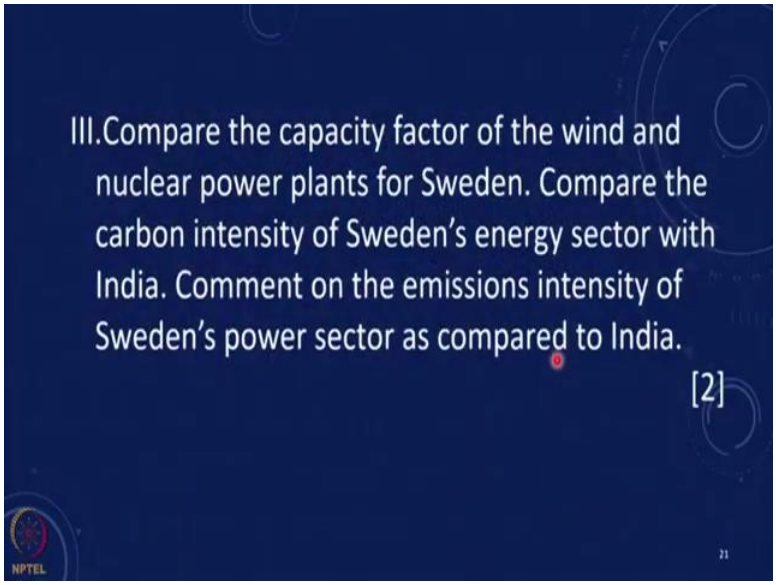

We are also asked to compare the capacity factor of this. Obviously, capacity factor of nuclear is higher. We expect that it runs as a base load plant, wind will the capacity factor is constrained by the supply of the wind. And now we are asked to compare the carbon intensity of Sweden's energy sector with India and to comment on the emission intensity of Sweden's power sector as compared to India.

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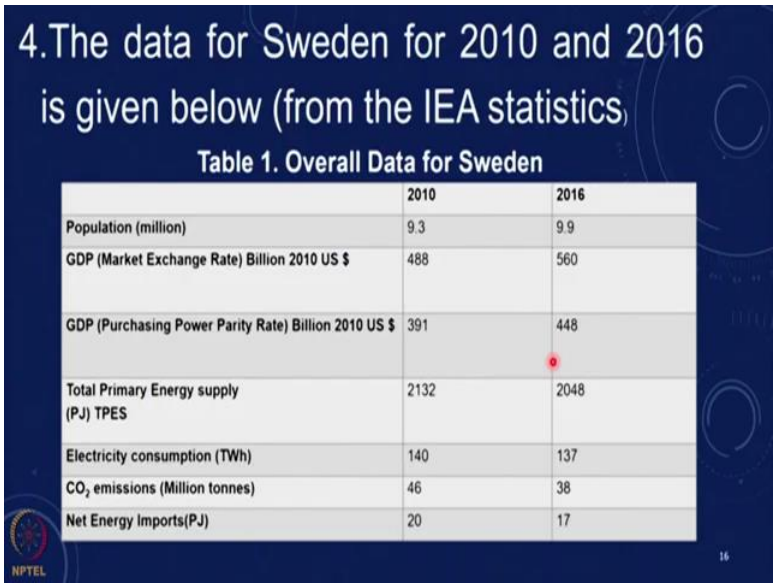

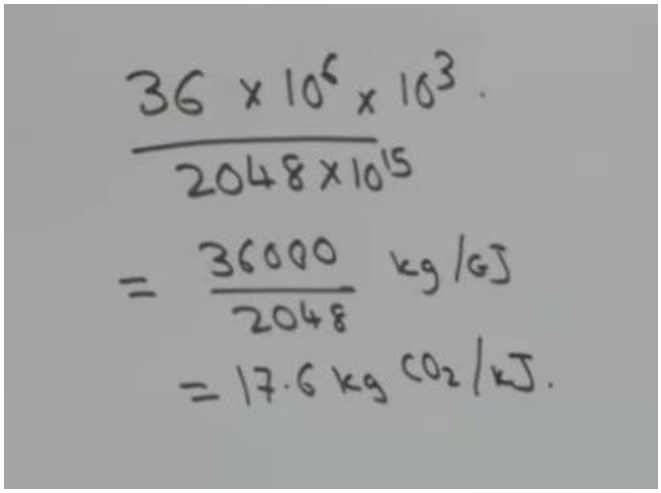

So, in order to do this the carbon intensity let us see, we have the total CO_2 emissions, which is given to us as CO_2 emissions million tons, let us take it for 2016. This is 36 million tons. And this is to be divided by the amount of electricity that we are generating. And the total or sorry we are doing it per unit of primary energy, so, by 2048 primary energy and this is in Giga joules. So, this is 10 raised to 15. If we want to do this in terms of kg we will have a 10 raised to 3 factor and you will find when you calculate this, this comes out to be 36,000 by 2048, 17.6 kg of CO_2 per Giga Joule.

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Table 2. Overall Indicators for India and the World 2016

	India	World
TPES/capita	19 GJ	77 GJ
TPES/GDP $_{MER}$	14.6 MJ/US$	7.4 MJ/US$
TPES/GDP $_{PPP}$	4.6 MJ/US$	5.3 MJ/US$
CO_2/TPES	57.6 kg/GJ	56.2 kg/GJ
CO_2/capita	1.6 tonnes	4.3 tonnes

Let us look at now what were those India numbers. CO_2 for primary energy for India and the world are almost the same, Sweden is lower than this. And the reason for this is that if you look at Sweden, there is a significant share of renewables and hydro and India is predominantly coal based and with the result that we expect that the emissions intensity of Sweden's power sector is going to be lower than that for in India, significantly lower than that of India.

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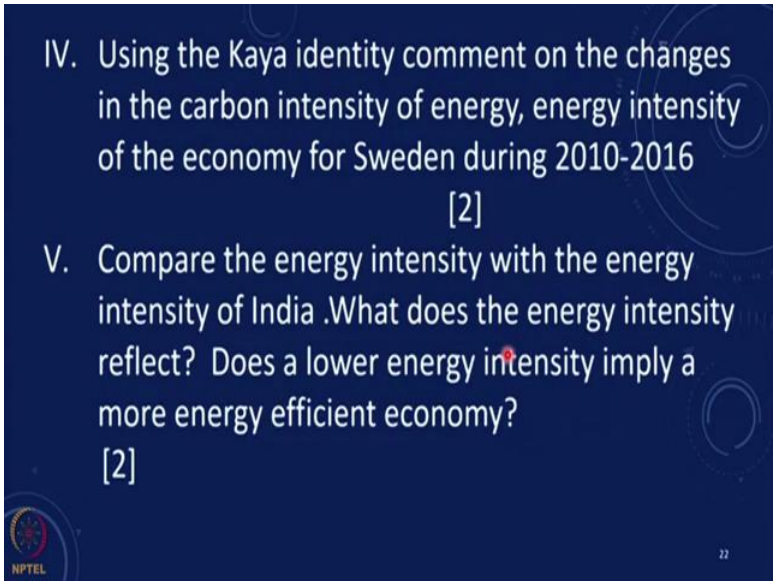

The next part of the question is, you has asked to use the Kaya, using the Kaya identity, comment on the changes in the carbon intensity of energy, the energy intensity of the economy for Sweden during 2010 to 2016. And then compare this energy intensity with energy intensity of India. What does the energy intensity reflect? Does a lower energy intensity imply more energy efficient economy?

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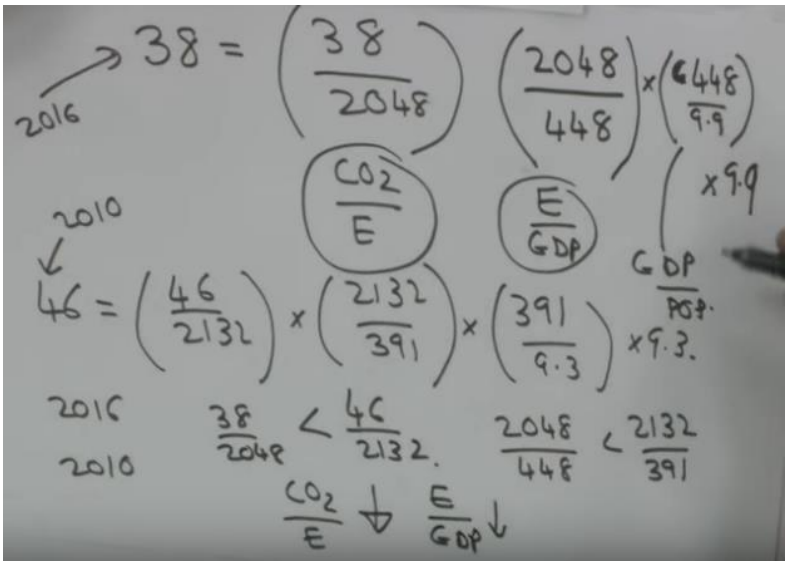

So, Let us look at the Kaya identity. If you look at for Sweden for 2016, the total CO_2 emissions, CO_2 emissions is 38. So this is 38 by 2048. This is CO_2 per unit energy into energy, per unit GDP, E by GDP into GDP per population into population. And the next year this becomes 46, this is, this is sorry this is the recent year 2016. In 2010, it was 46 which was 46 by 2132 into

2132 by 391, let us just check which year it was, let us see the values. 46 is the sorry 46 yeah 46 is for 2010 and this is for in 2010, we had this as 2132, the purchasing power parity, this was 391 and then this was 391 by 9.3 into 9.3.

So, if you look at this first term in 2016, 2010 this turns out to be, the number is CO_2 Kg's you see what happens in this case is that we have a decrease in the carbon intensity, 38 by 2048 is less than 46 by 2132, there is a carbon intensity of energy decreases and this decreases from, this decreased by about 14 %. The energy use per so, there is an overall decrease in the CO_2 emissions, because the carbon intensity has decreased as well as the energy intensity of the economy.

So, that means both these numbers when you say 38 by 2048 has decreased, this 38 by 2048 is less than 46 by 2132, this is decreased and similarly 2048 by 448 is less than 2132 by 391. So, both the carbon intensity CO_2 per unit of energy has decreased as well as energy per unit of GDP has decreased. So, even though the GDP increased and the population increased, overall the total CO_2 emissions has decreased. So, this is the situation for Sweden.

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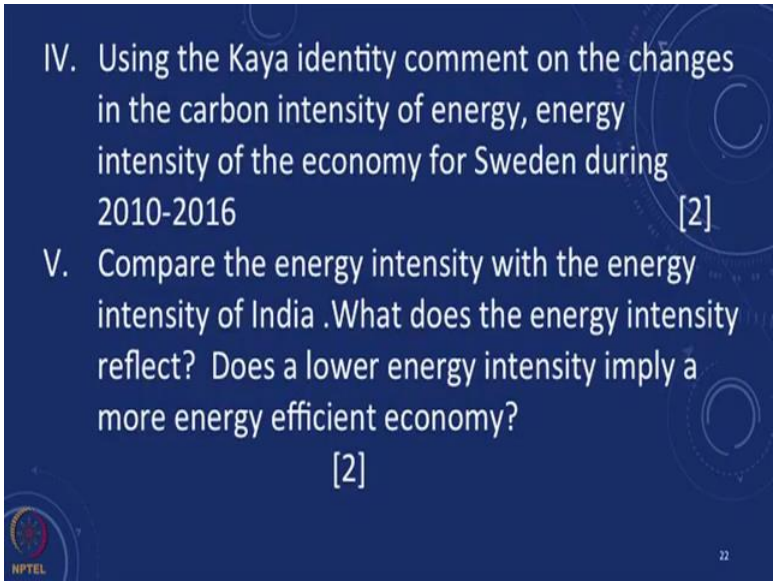

Then the next part of the question is that, comment on the, compare the energy intensity, compare the energy intensity with the energy intensity for India. The energy intensity of Sweden is similar to that of India. But it is less than if you look at these values the energy intensity per unit of GDP if we are looking at that, in the case of India it is about 4.6 mega joules per US dollars. And in the case of Sweden when we when we calculated this, we saw that it is almost similar.

The next point was that, what does the energy intensity reflect? The energy intensity can reflect the efficiency in your system. If you have a more efficient use of energy then we would have this the energy intensity per unit of output would decrease, but does not energy lower energy intensity imply a more energy efficient economy? This is not necessarily true. Because the energy intensity of the economy also depends on the structure of the economy, where does the GDP come from?

If the economy produces more industrial goods, the energy requirement is higher if it is more in manufacturing, if you are doing steel, cement, aluminum, we will need more energy. However, if the energy inten the GDP is coming from the services sector, the energy requirements are less. So, lower energy intensity, if the structure of the economy is the same, and the GDP is coming from the same sectors, then of course, if you have a lower energy intensity it means that we have become more efficient.

But if the structure has changed, it is possible that a lower energy intensity can be done because we have shifted from manufacturing to services and even though we have not improved the efficiency.

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And so, then the last question which is there in the paper is comment on the difference in perspectives and strategies for Sweden and India vis-à-vis, the global climate change negotiation. So the first point which should be kept in mind is that Sweden, when we look at the CO_2 per population, it is significantly higher than that of India, it is also the, it is about 3.83 tons per capita. The income is higher than that of India.

So, Sweden would be one of the countries for which would be considered as a developed country. It has also now gone to a stage where the energy used per capita is significantly higher than is higher than the world average. It has an onus to reduce its energy intensity, it is fortunate that it already has a mix of energy which is less carbon, which is the CO_2 per unit of energy is lower than that of India or of the world average.

And the negotiation strategy for Sweden would be where it is trying to actually stabilize and it is already contributing more to the problem. It is it is in one of those countries which has already utilized the reasonable part of the of its CO_2 budget. India on the other hand is a developing country, where all the different components, the infrastructure is not yet in place and we still need significant increase in the basic energy services. Sweden may have almost saturated in terms of energy services.

So, in a sense we are approaching the problem from different perspectives. India wants to have space to grow and try to grow that sustainably which is reflected in our Paris commitments. Sweden on the other hand, could take a stance that we would like to try and minimize, but it would try to it is already one of the countries which is one of the, on a per capita basis, higher emitter. It would like to negotiate for emission targets based on per GDP, rather than per capita. India would like to negotiate based on a per capita basis.

However, having said that Sweden is actually one of the countries which has been pushing for higher enables and strategies which will reduce and mitigate climate change. Sweden has also made ambitious targets and as you saw over the years, in this time period 2010 to 2016, the overall CO_2 emissions have actually declined.

So, from the Paris agreement of view, different countries could have different prospective based on what is their status and what is their expected growth. So, with this, we complete the solution of this paper, you may want to just look at how you have performed and then if you have any questions, please feel free to mail those to us.