Energy Resources, Economics and Environment
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Lecture 8
Renewable Energy Sources- Part 2

Let us know move ahead and look at solar, so in the case of solar, solar is much more predictable and when we talk about solar isolation.

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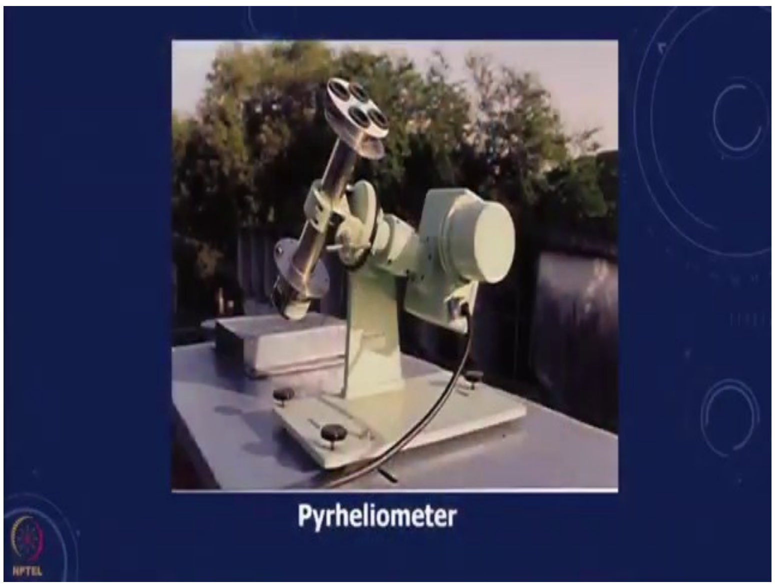

We are looking at the direct and diffuse, so we have a direct and diffuse, if you looking at direct isolation, this is an instrument which is used to measure the direct beam insolation, this is called the Pyrheliometer, this is focus, so that it is directly depending on the position of the sun, it will be taking the direct normal beam radiation to the sun and you have this is measurement.

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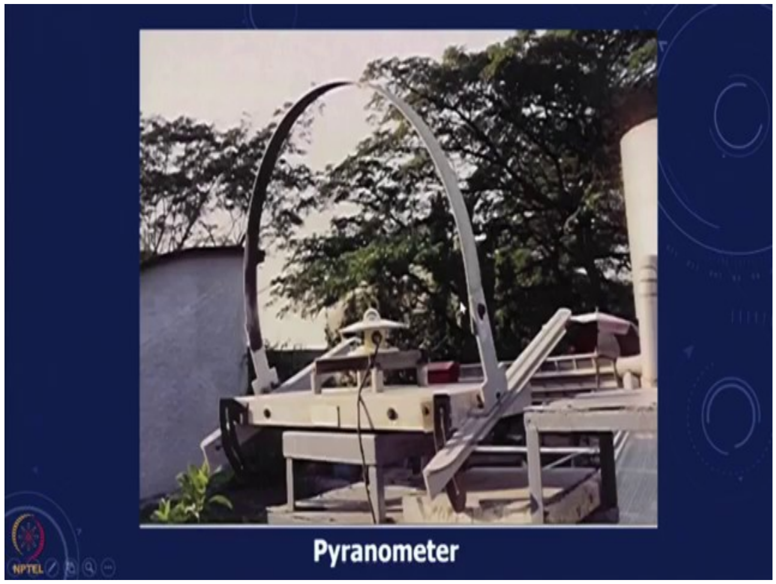

You also have what is known as a Pyranometer and the Pyranometer can be used for measuring diffuse radiation or total, this is a blocking sheet which can be used to block the direct and then what is measure becomes only the diffuse, if we remove this then we will get the total insolation which is on a horizontal surface and that will be the global horizontal insolation. And so, the direct plus diffuse will give us the horizontal and these are the instruments that can be used to measure. Most of the measurement stations will have these types of instruments.

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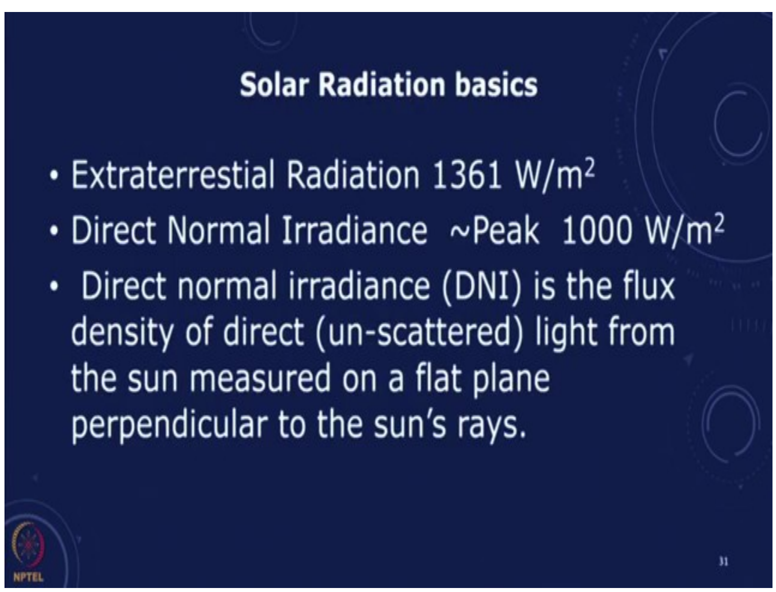

$I_{sc}\ \ 1361\,W/m^2$

DNI

And the solar constant I_{sc} which is incident is of the order of 1361 W/m^2, that is the total amount of solar isolation available per meter square of surface. When it comes through the atmosphere some of it gets scattered, some of it comes down and diffuse, some of it gets absorbed.

And what we have is what is known as the direct normal irradiance DNI and DNI at any point of time when we talk about the solar photovoltaic we usually have a standard which is based on a thousand watt per meter square and we create the characteristics for that insolation, when the insolation is lower the output would be lower. So, DNI is the flux density of the direct un-scattered light from the sun measure on a flat plane perpendicular to the sun's rays.

And this DNI that we talk about which is, so this is DNI is perpendicular to the sun's rays, so that it is you have the normal irradiance which is there and this flux varies over the day as the sun rises and the there is a peak and then it goes down in the evening. When we look at the DNI every hour we can measure the DNI and then make a plot, we can take the aggregate amount of the irradiance over the year and that is plotted as the annual DNI, so those are the kind of values which are put.

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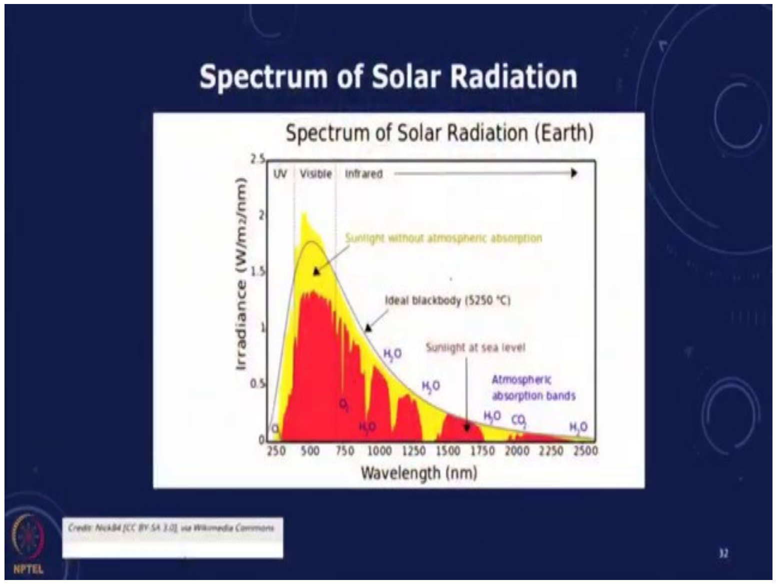

When we look at the spectrum of the solar radiation if you see this, will have the sunlight which is there some of it is observed then it reaches, this is at different wavelengths and some of it is in the visible range and in the infrared in the ultra-violet and all of this incident onto the device and depending on the characteristic of the device we have an efficiency which is there and this is used to convert the energy.

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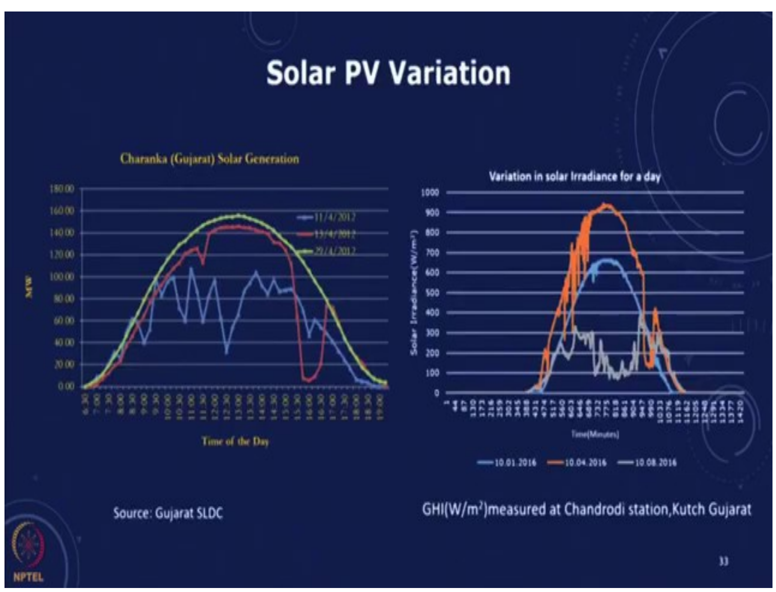

So if you look at now, this solar irradiance these are from 3 a few of the sites which are there where there are been solar plants and you can see that in some cases you have this pattern but because of cloud cover for some hours there is a drop in the irradiance and this is from a site in Gujrat for a particular day one of the days you have no cloud cover and this can see that the generation megawatts is follows the classic example of what we expect from solar PV plant.

On another day there is some cloud cover at this point and then there is a cloudy day in this one is a cloudy day with number of cloudy hours and disruptions, so these are the kind of things which I told you in terms of the interruption and the variability which is there in solar.

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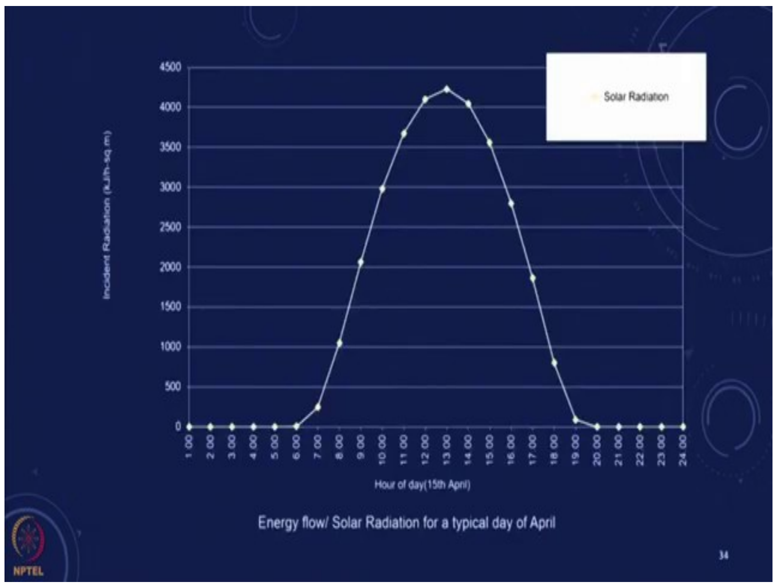

Solar is much more predictable as we said that with the different kinds of you can measure this is with a different unit its kilo joules per hour square meter. Usually we will put it in terms of watts per meter square and then we can take watt hour per meter square multiplied by the number of hours and then over the year you will get something like a kilo watt hour per meter square, per year.

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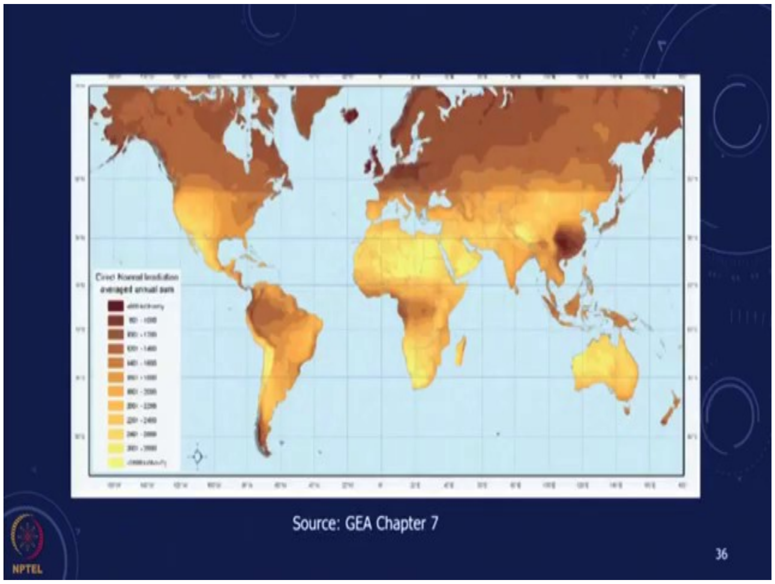

And this is the global solar irradiance and you can see this is the direct normal DNI which is there and you can see the yellow region these regions are the ones with high DNI. In the Indian context we have reasonably good DNI across most parts of the country.

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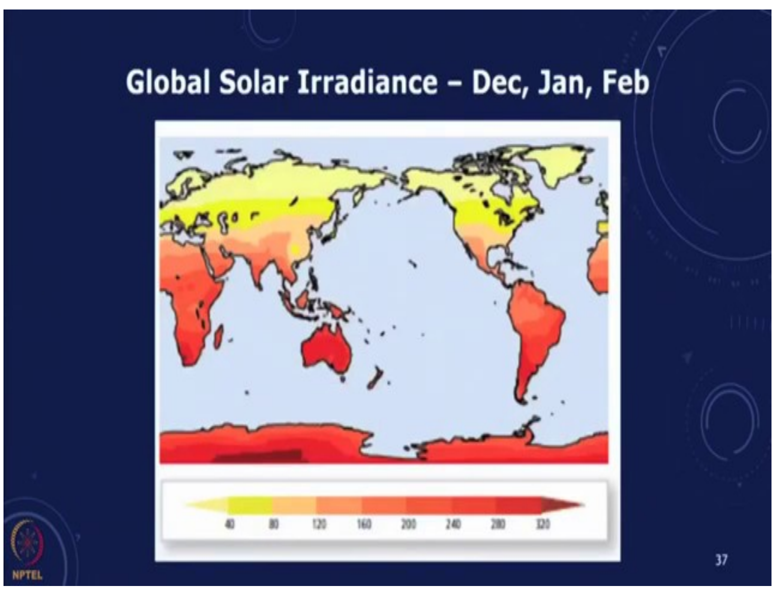

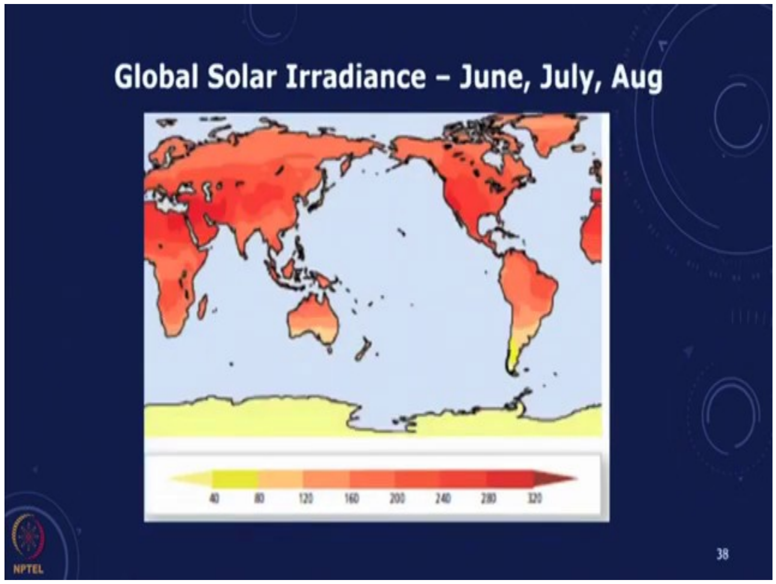

And there is a variation ofcourse see this is the kind of average global irradiance and you can see this is in watts average in watts per meter square over the months of December, Jan, Feb and this is June, July, August this is again both of these are from the global energy assessment.

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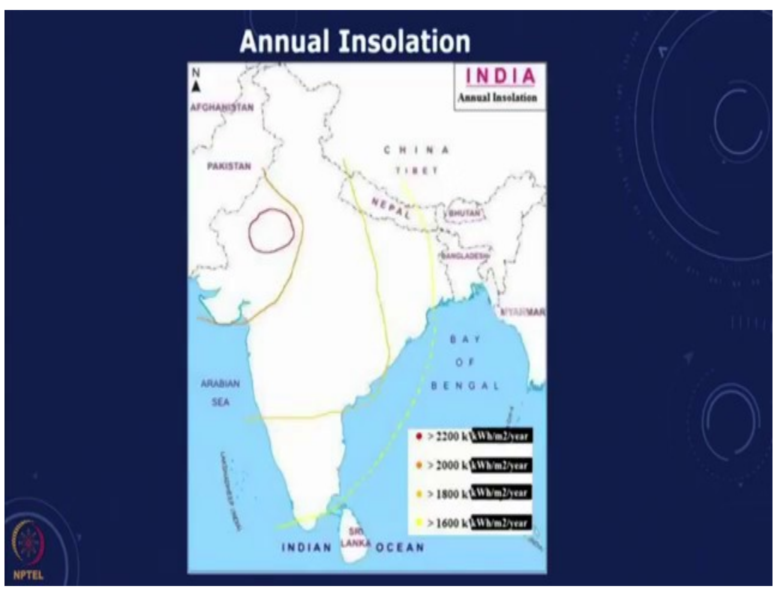

In the case of India, you find that most large parts of the country have, most of the country has DNI greater than 1900 kilo watt hour per meter square and some of these regions for instance this is more than 2200 and so this is quite a good DNI.

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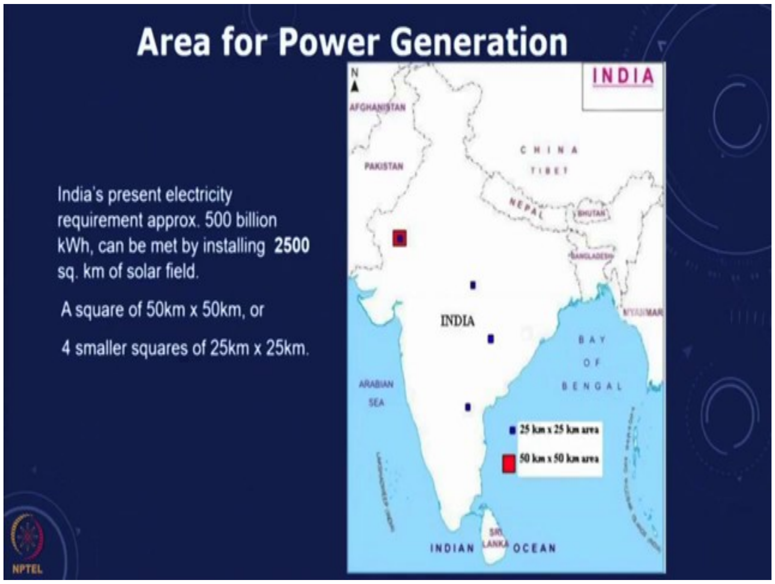

Now in order to make a calculation if we look at the total amount of electricity that we require we can take that electricity divide it by the DNI that we have, take the efficiency of the cell and then calculate what is the area that is required and if for instance if you are talking of 500 billion kilo watt hours we can see that this can be met by installing about 2500 square kilo meters of 50 into 50 km or 4 smaller squares of 25 km x 25 km.

And so really speaking this location which has been selected is location which has the highest insolation in terms of DNI it is also a location which is a desert and relatively low population density. However, still you know getting 50 km into 50 km is difficult creating the transmission and distribution line, creating the storage in actual practice when we try to get land, land is always difficult to acquire.

And the requirement for land, the requirement for water in terms of the cleaning the panels and in the case of solar thermal even as a working fluid, these are some of the problems in terms of the solar penetration.

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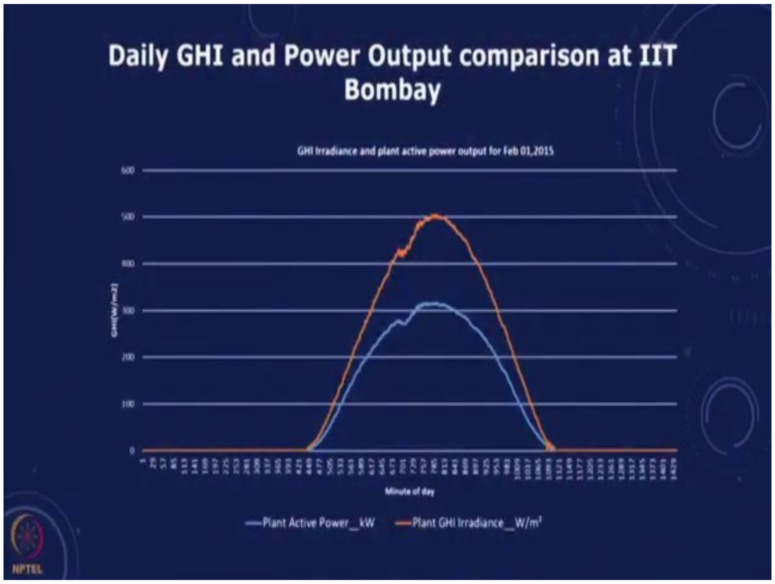

As I told you for the you can see this is the global horizontal insolation watts per square meter for a particular location of a PV module in the IIT campus and you can see that the generation actually follows the insolation data.

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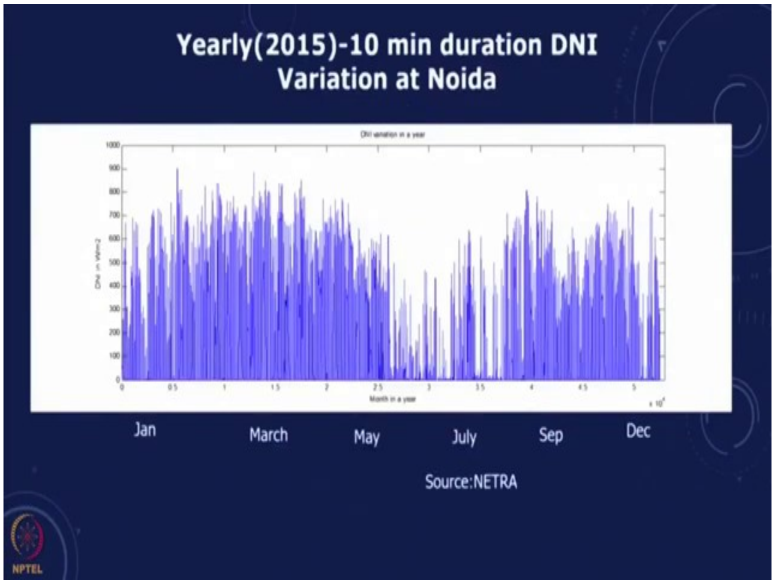

We can also look at the DNI variation over the year and you can over this is for a particular site at Noida and you can see that every day the DNI goes up and down but there is a variation in the seasons and there is a fluctuation and so this is one of the issues when it comes to solar but when we look at solar there are large tracks in the Indian context we have a significant amount of solar radiation, most parts of the country are good solar radiation.

Most of the solar is happening though in mostly in the west and the south, east and north-east relatively have less solar radiation, so we have this situation where when we talk about fossil fuels, it was mostly in the east and little bit in the center most of the solar and the wind is happening more in the west and the south, so there is a sort of regional disparity in terms of the kind of resources which are available.

Let us now look at some of the other sources of energy, if we look at tidal, tidal is the renewable energy source where it is not dependent on the sun but it is actually the moon, so the gravitational effect of the moon on the earth causes the high tide and the low tide and the principle typically in a tidal situation of course you can have tidal turbines which are in the stream just like the wind turbines but in the other case we allow the water to come in at the high tide and then we block it and then we release the water at the low tide.

This difference between the high tide and the low tide that is called the tidal range that gives us the head for running the turbines which gives us the power generation, so the power generation happens only at a fraction of the time when we are releasing the water during the low tide and it will ofcourse be in.

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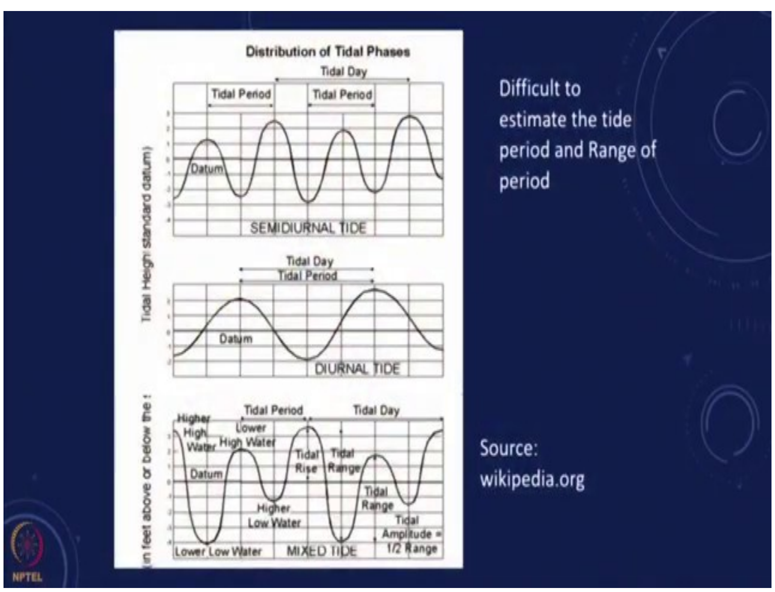

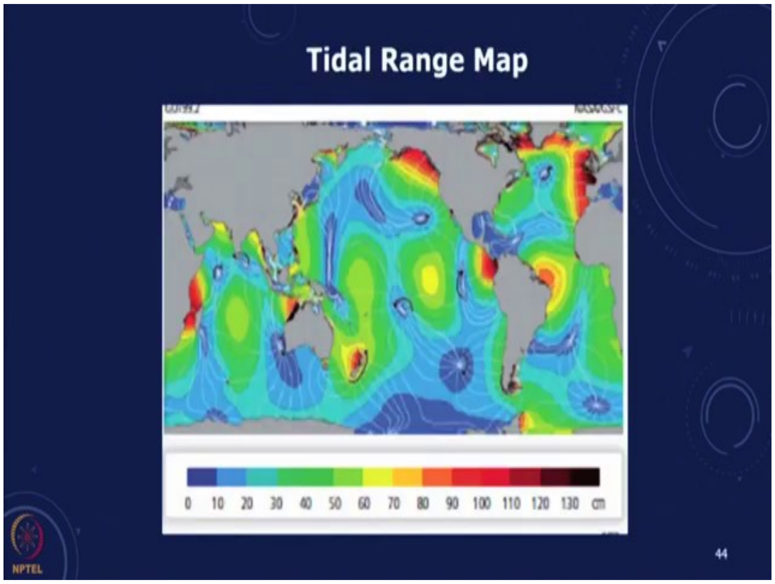

So, in the case of this kind of data we will need to have what is the tidal you know there will be a daily tide or a semi diurnal tide, there will be a tidal range between the high tide and low tide and this has to be mapped.

This has been for all locations of the course there are ranges of tides which are provided and this is the tidal range map which is given in the, you can see ofcourse that we are looking at a tidal range of 10 to 30m would be, could be cost effective again depending on the location and the kind of things one can think in terms of. In India, we have not yet built there is a plan to build and I am not sure what is the status of that of the coast of in the Bay of Bengal of the coast of Sundarbans.

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Barrage	Country	Capacity (MW)	Power generation (GWh)	Construction costs (million USD)	Construction costs per kW (USD/kW)
Operating					
La Rance	France	240	540	817	340
Sihwa Lake	Korea	254	552	298	117
Proposed/planned					
Gulf of Kutch	India	50	100	162	324
Wyre barrage	UK	61.4	131	328	534
Garorim Bay	Korea	520	950	800	154
Mersey barrage	UK	700	1 340	5 741	820
Incheon	Korea	1 320	2 410	3 772	286
Dalupiri Blue	Philippines	2 200	4 000	3 034	138
Severn barrage	UK	8 640	15 600	36 085	418
Penzhina Bay	Russia	87 000	200 000	328 066	377

http://www.irena.org/DocumentDownloads/Publications/Tidal_Energy_V4_WEB.pdf

There is a plan to build a tidal plant, there is also a plan at the gulf of Kutch, the largest tidal plant is the one in France which is a 240 MW La Rance plant which has been operational for decades and it is also a tourists attraction, there is a recent one which is being built in Korea in the Sihwa lake somewhat 254 MW.

So, tidal as of now there is a potential it is not yet a commercial technology there are a few projects, they are demonstration projects, they can be near cost effective but we do not expect them to have a very major role in the future unless there are technology breakthroughs. In addition to tidal there is also something called the ocean OTEC, or the Ocean Thermal Energy Conversion.

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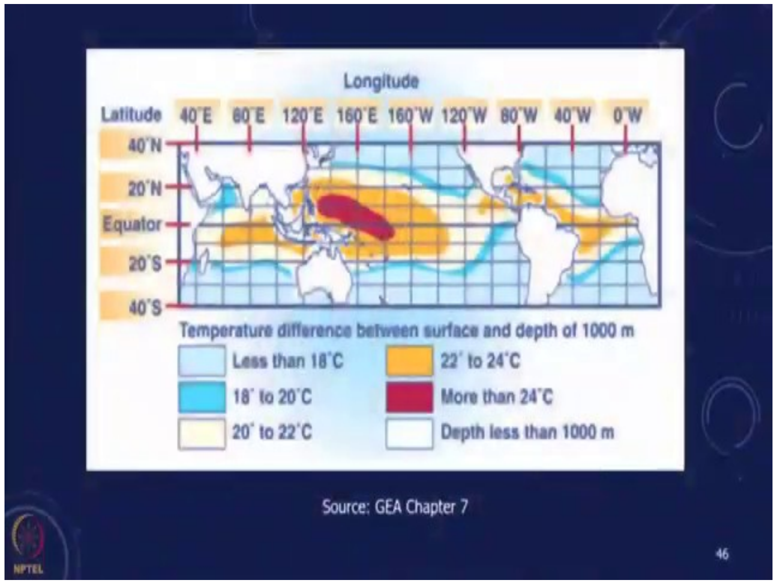

And this basically is using the principle that the surface of the ocean is much warmer than the water which is there at the depth. And because of this it is possible to have a normal ranking cycle where we use the temperature this temperature difference to generate electricity and the advantage that we have is that we have a large volume of water and even though the temperature differences are relatively small in the sense that we are looking at temperature differences of 18 - 20^{o} even though they are relatively small because there are large volumes we can get, we can generate reasonable amount of energy.

We had the largest plant being planned of the cost of Tamil Nadu it was a 1 MW power plant and the problem was that most of the components were tested however when it was out in the field the pipeline the HDP pipeline 1.1 km pipeline kept getting ruptured and because that was not able to establish that was the project was abandoned. There are number of the, this is the most difficult challenge in the sense that it has to be put in the ocean which is the most the, most adverse and harsh environment.

But however, there is a significant potential to do this, in the case of wind also in many of the countries in Europe the land for wind is not available and the plan is now to move off shore. In the case of off shore, you we can have, essentially, we will have much higher wind speeds and we can have large wind farms and that is the way this is going offshore is costlier again there are technological challenges but this has been the way we going.

In the case of wind also we have gone for larger and larger plants and now we have a single turbine which can be generated of the order of 10 megawatts. So, this is in terms of we have looked at tidal and we have looked at ocean thermal.

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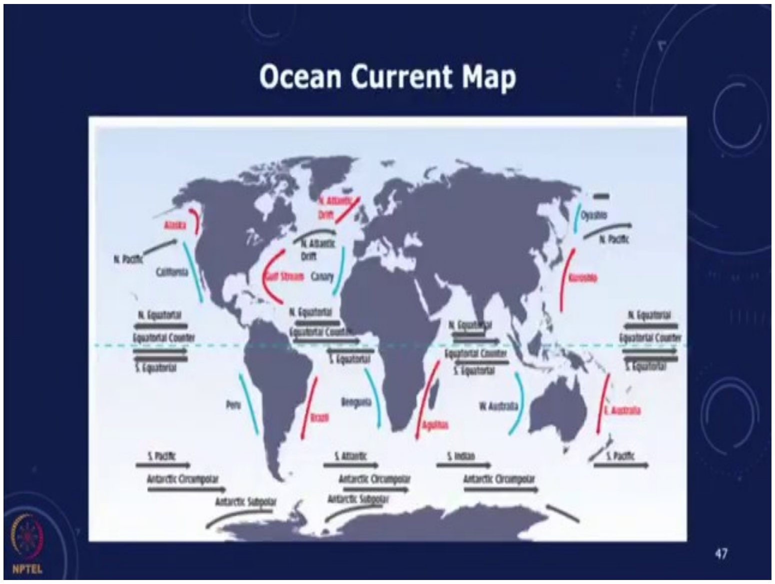

Then there is also we can also look at these ocean currents and it is possible to use some of these ocean currents in terms of energy generation.

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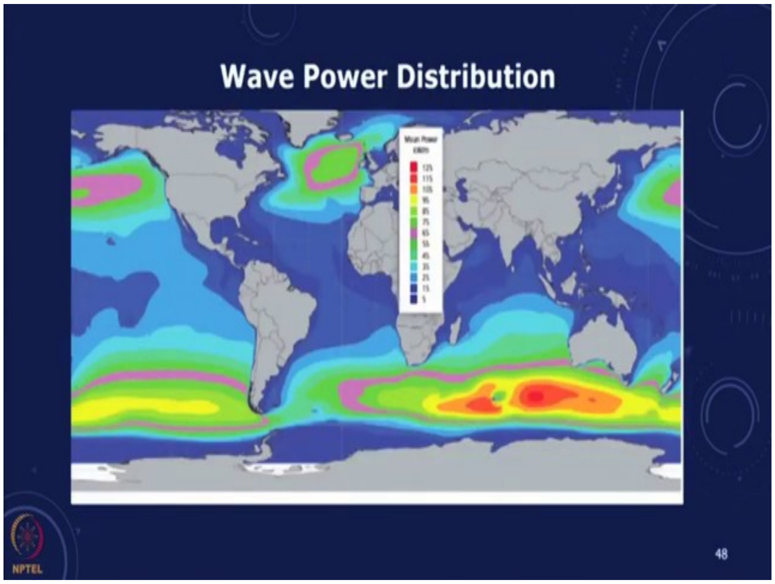

The other possibility related to the course is to have the energy which is available in waves and to harness that and in order to do that what happens is that see on the surface of the water because of the wind we have the waves and the waves have the crest and troughs and we have number of different devices which can be used you have the oscillating water column and you have the Edinboro duct and you have the Pelamis different kinds of devices which bob up and down and that movement reciprocating air is converted into electricity.

This has the largest number of patents which are available for wave power. The problem is that this is all distributed you need to have a wave for taking out that power, we need to have a wave for taking that power and converting it into electricity and then evacuating that electricity and connecting it to the shore. So, this is again something where we do not that is a reasonable amount of potential.

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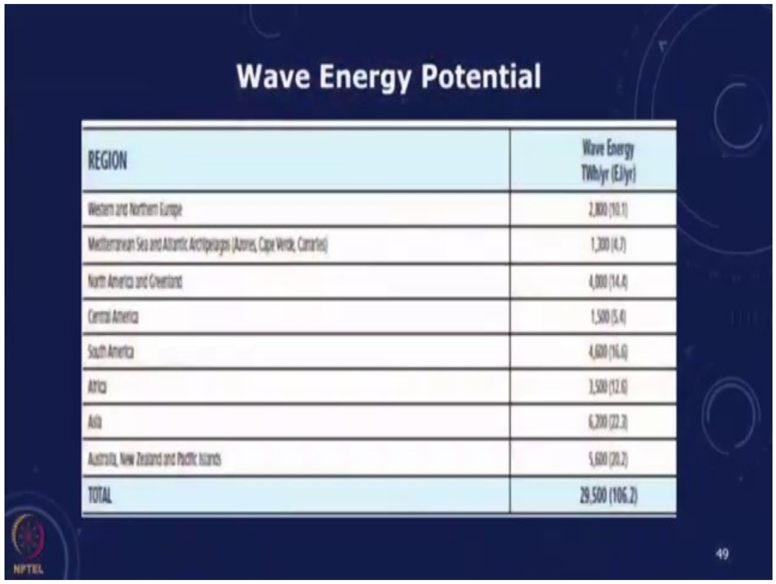

REGION	Wave Energy TWh/yr (EJ/yr)
Western and Northern Europe	2,800 (10.1)
Mediterranean Sea and Atlantic Archipelagos (Azores, Cape Verde, Canaries)	1,300 (4.7)
North America and Greenland	4,000 (14.4)
Central America	1,500 (5.4)
South America	4,600 (16.6)
Africa	3,500 (12.6)
Asia	6,200 (22.3)
Australia, New Zealand and Pacific Islands	5,600 (20.2)
TOTAL	29,500 (106.2)

And this is that you can see in different regions you can see that the total terawatt hour which we are looking at exajoules it is about 106 EJ it is very large potential but cost-effective extraction is an issue, there could be breakthroughs and this could provide reasonable amounts of requirement especially for islands and coastal regions. So, we looked at tidal, we have looked at OTEC, we have looked at wave and the other source of energy as we talked about is the geothermal energy.

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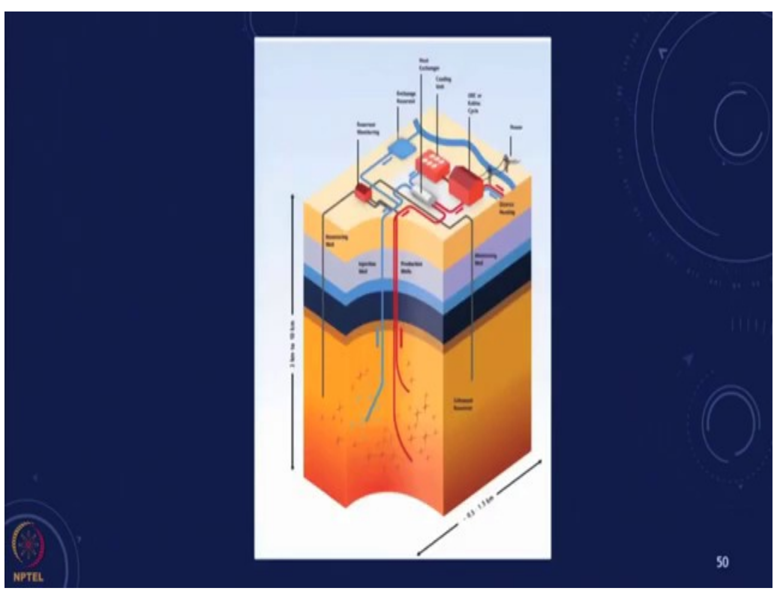

And in the case of geothermal as we said there is that the at the depth the temperatures are much higher and then you may look at the water coming in contact with this, we have essentially hot water or steam coming out, there are many natural hot springs where these come out and these are usually tourists attractions.

Here there are many different technologies where we can have an injection well and an extraction well where you inject water inside and or a working fluid inside and then you can have an organic ranking cycle and have power generation. If you have lower temperature, we can also directly use it for heating or we can use the vapor absorption refrigeration system using for cooling there are also geothermal heat pumps and geothermal, so you can have ground.

From the ground if you take things the temperatures are 5^o , 6^o lower and you can run, you can save energy when you are trying to heat or cool a space, so that is again another application there are many different countries where this is a commercial technology cost effective but it needs I will be in areas where there is already the falls and you have the steam emerging at high temperatures.

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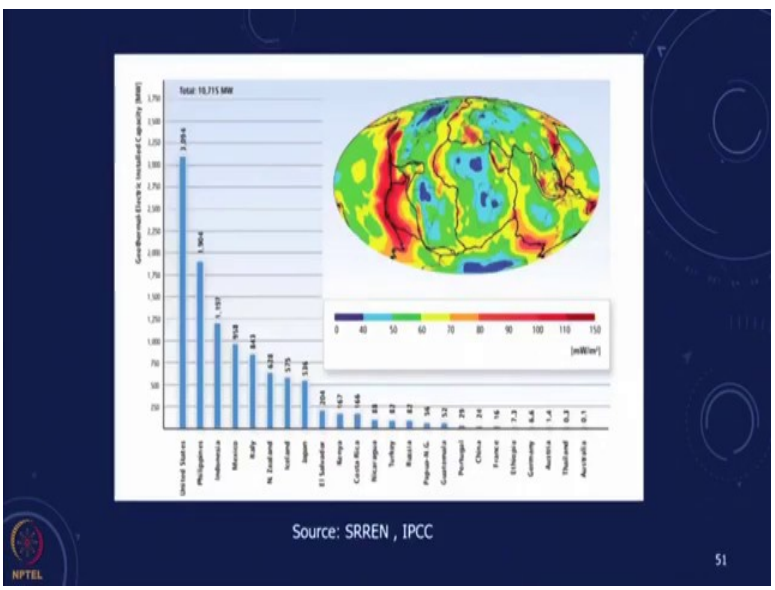

So, this is, this gives you an idea of some of the different countries and the kind of geothermal installed capacity and you can see Indonesia, Island, Philippines a number of different countries where there is a geothermal capacity.

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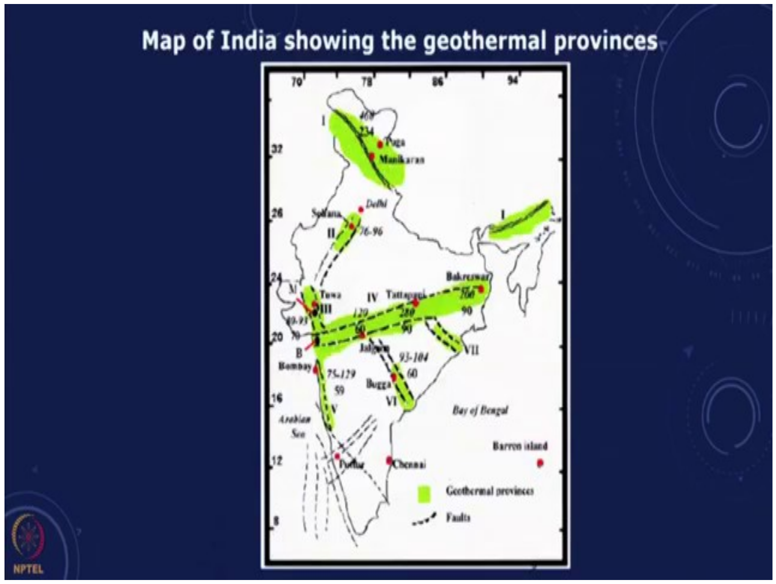

And this is a map showing the geothermal falls. Before we look at that in the case of India these are the geothermal provinces and if you see the in the Indian context the around the fault areas these are the areas where you have the geothermal but the temperatures in most of the case the temperatures are relatively low. In some cases, in the Puga valley we are getting temperatures of 200 centigrade. So, this kind can be used for power generation there is a pilot being planned at Puga valley, many of these are the places you can use it for cooking, you can use it for heating and in we do not expect geothermal to have a very major role in the Indian context but locally this can provide some of this requirement.

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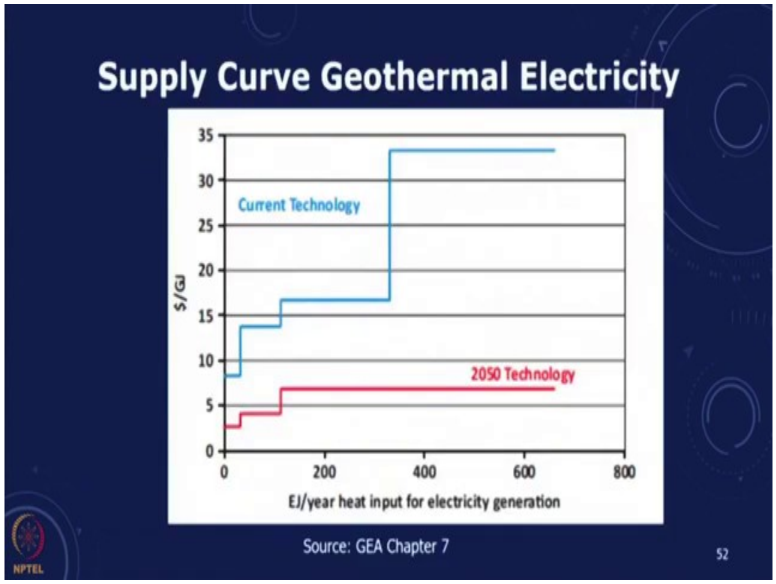

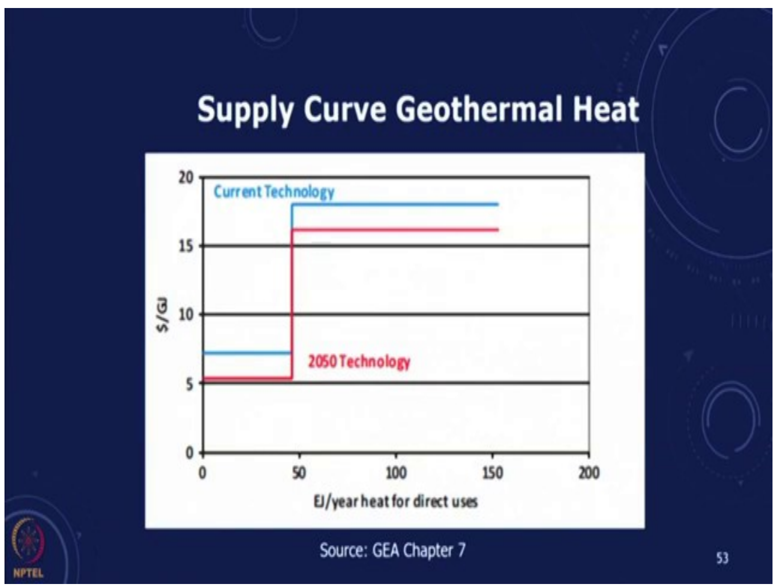

The supply curve for we talked about supply curve, the supply curve for geothermal with current technology you can see that we can get of the order of 200 EJ or 300 EJ at different kinds of prices and with new technology of course the prices will go down, that is what the supply for geothermal electricity. And this is for supply for geothermal heat, so similar kinds of supply curves are available for many of these and this is available in the global energy assessment resource chapter. We come to now another energy source which is in the Indian context quite important, it is biomass.

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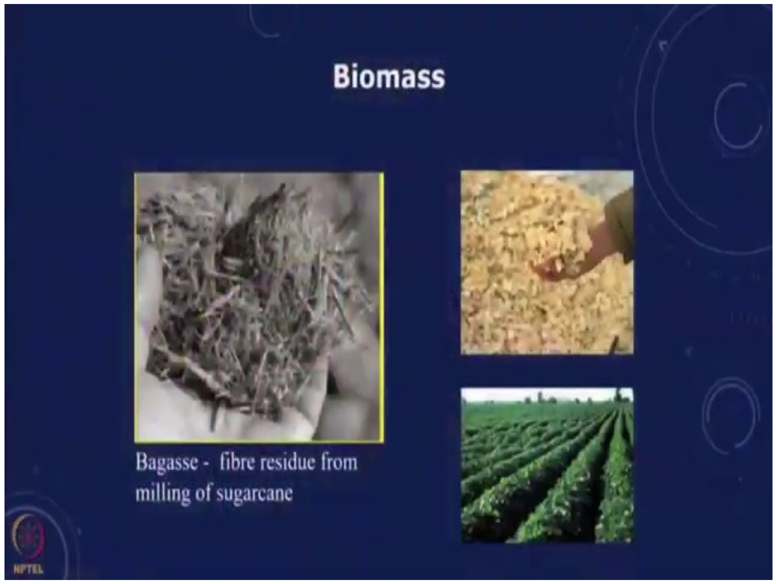

And biomass could be an agricultural residues, crop residues, it could be wastes which are there and cattle dung and then this biomass of a variety of such biomass is available. There are many different processes and process roots for conversion of this biomass.

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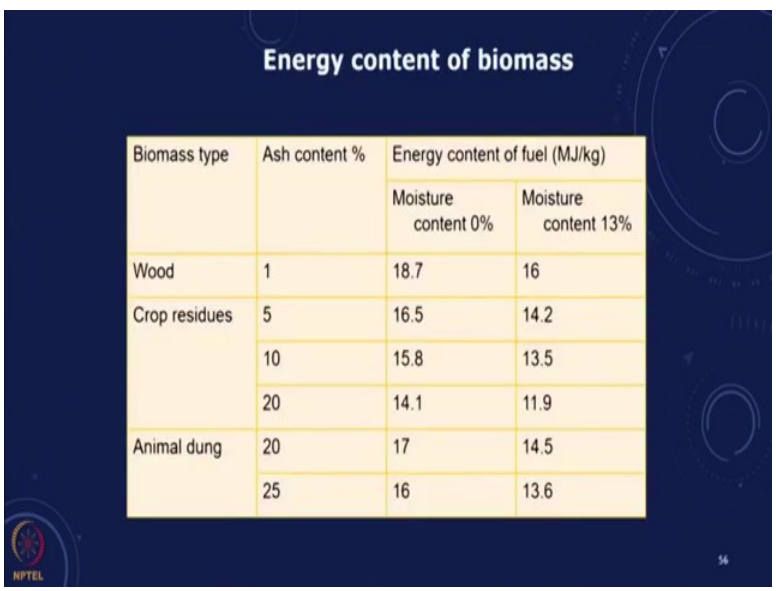

Biomass type	Ash content %	Energy content of fuel (MJ/kg)	
		Moisture content 0%	Moisture content 13%
Wood	1	18.7	16
Crop residues	5	16.5	14.2
	10	15.8	13.5
	20	14.1	11.9
Animal dung	20	17	14.5
	25	16	13.6

When we try to map this biomass each of the biomass has the depending on the ash contained and the moisture contained, you have a certain energy content of the fuel and you can see that in all of this has the energy contained between we are talking between 12 to 19 mega joules per kg.

Remember that we were comparing this with when we talk of oil it is about we are talking of 40 mega joules, coal is about half of that but it is reasonable source, so it is slightly lower than the energy contained in coal but it is something which is abandoned and of course in some cases they already have alternative uses, it is being used biomass is being used as fodder for cattle, it is being used as feed stock, it is being used hatching for houses.

So we have to see whether bottom of the supply and demand and we have to also look at if you talking about animal dung, we look at how do we collect it, how do we process it but we can estimate an all of this when we look at getting the estimates of this, this is, these are now stocks, so we will have to have distributed ways of making this calculations.

When we do these calculations, we would need to look at for instance, we know in different regions of the country or regions of the world what is the wheat production, rice production and based on that, and based on the production we can find out per ton of product.

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Table 2.1. Crop Residues: Residue Ratios, Energy Produced, Current Uses

Crop	Residue	Residue ratio[a]	Residue energy (MJ/dry kg)[b]	Typical current residue uses[c]
Barley[d]	straw	2.3	17.0	
Coconut	shell	0.1 kg/nut	20.56	household fuel
Coconut	fibre	0.2 kg/nut	19.24	mattress making, carpets, etc
Coconut	pith	0.2 kg/nut		
Cotton	stalks	3.0	18.26	household fuel
Mustard Cotton	gin waste	0.1	16.42	fuel in small industry
Groundnut	shells	0.3		fuel in industry
Groundnut	haulms	2.0		household fuel
Maize	cobs	0.3	18.77	cattle feed
Maize	stalks	1.5	17.65	cattle feed, household fuel
Millet	straw	1.2		household fuel
seed	stalks	1.8		household fuel
Other seeds	straws	2.0		household fuel
Pulses	straws	1.3		household fuel
Rapeseed	stalks	1.8		household fuel

How much tons of residues are produced and we can multiply that, we can take the yield in terms of how much area under plantation, what is the yield multiply that by the residue ratio and then we will get the amount of residue, we can get the energy content of the residue.

Also depending on the growing season and the harvesting season the residues will be available at a particular point of time. So, one of the recent controversies and which has been in the news is has been about the pollution in many of our cities including Delhi and the problem with the air quality has been blamed on the stubble burning which is happen in Haryana, in Punjab and the crop residues and the stubble and it is possible of course to gasify it use it for and we have to work out the things. So, this is the kind of potential.

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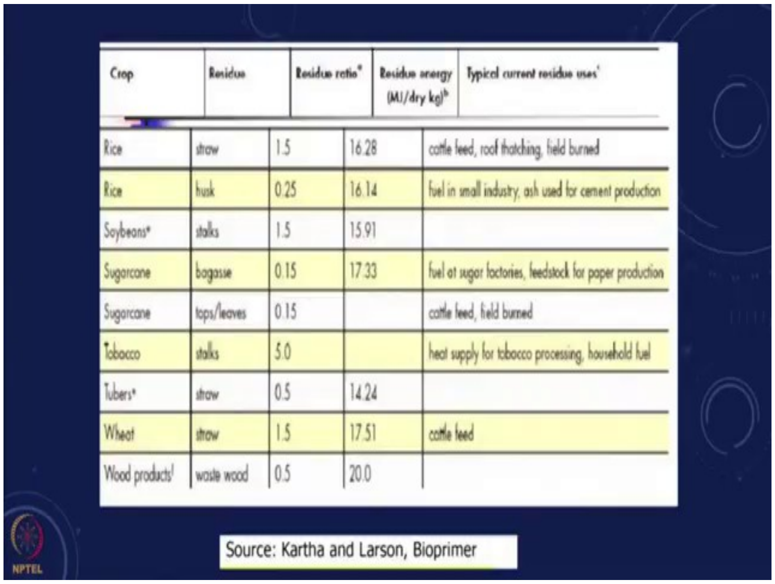

Crop	Residue	Residue ratio[a]	Residue energy (MJ/dry kg)[b]	Typical current residue uses[c]
Rice	straw	1.5	16.28	cattle feed, roof thatching, field burned
Rice	husk	0.25	16.14	fuel in small industry, ash used for cement production
Soybeans*	stalks	1.5	15.91	
Sugarcane	bagasse	0.15	17.33	fuel at sugar factories, feedstock for paper production
Sugarcane	tops/leaves	0.15		cattle feed, field burned
Tobacco	stalks	5.0		heat supply for tobacco processing, household fuel
Tubers*	straw	0.5	14.24	
Wheat	straw	1.5	17.51	cattle feed
Wood products[f]	waste wood	0.5	20.0	

Source: Kartha and Larson, Bioprimer

So, in all of this you can take the rice again the quantity of residue, the residue ratio and the residue energy. So that is how we can calculate the biomass.

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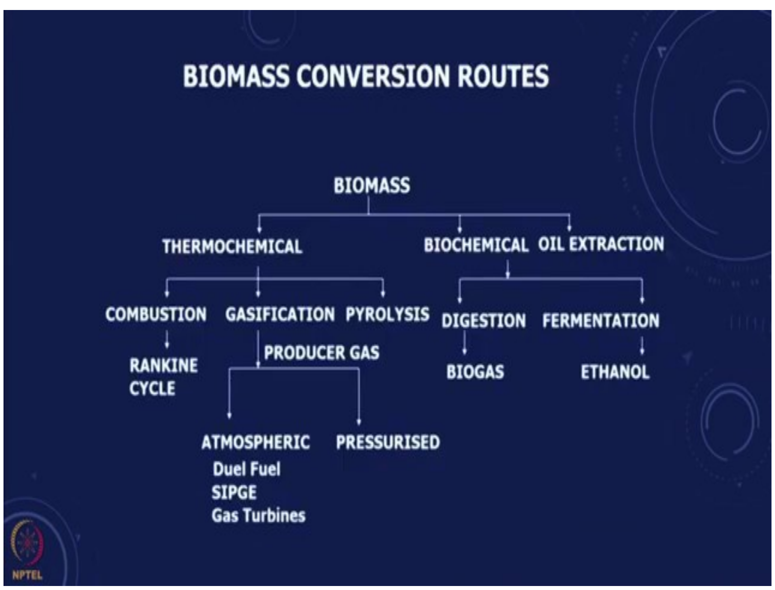

In the case of biomass, there are different possible processes there are thermochemical processes where we can look at if its combustion just like we have in a power plant the ranking cycle power plant, we burn coal and then we get steam and then we use that steam to run a turbine.

In this case we can take biomass, we can take biogas, we can take rice husk, we can burn it generates steam, generate power. The efficiencies are slightly lower than that of a coal-based power plant but it could be also co-fire you can have coal plus some biomass and the other route is instead of combusting it completely we can gasify that means we add less air so that it is partially gasified, it is gasified and you get carbon monoxide and hydrogen which is the producer gas.

And that producer gas then can be used to can run an engine, a diesel engine or a dual fuel engine or a dedicated producer gas engine or we can pressure it and use it for a gas turbine. Most of are Indian experience has been with atmospheric gasification and we have been using that gasified output for heating thermal or for running an engine and generating power, shaft work.

We can also think in terms of using this biomass for pyrolysis and getting liquid fuels, so this is thermal chemical, the rates of reaction are higher these are all chemical reactions biochemical is where we let now the microbes do the work for us, in the case of digestion, anaerobic digestion we get biogas, it settles down and we get biogas and we also get slurry and we can use this also for fermentation get ethanol, you can have oil extraction and you can have bio diesel then bio fuel.

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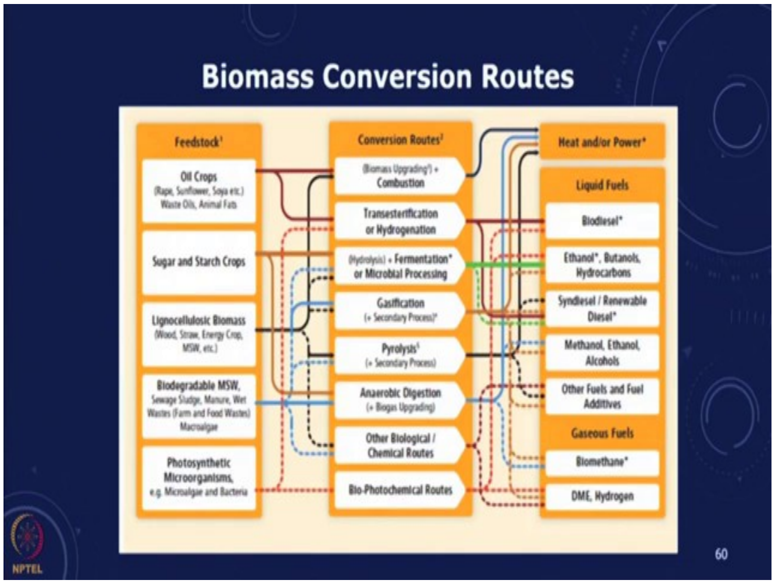

In the GEA and in this special report on renewables you can find all this again in terms of different biomass feed stocks, different kinds of conversion routes and different outputs in terms of heat to, heat or power or liquid fuels or gaseous fuels, so there are many different things which are possible.

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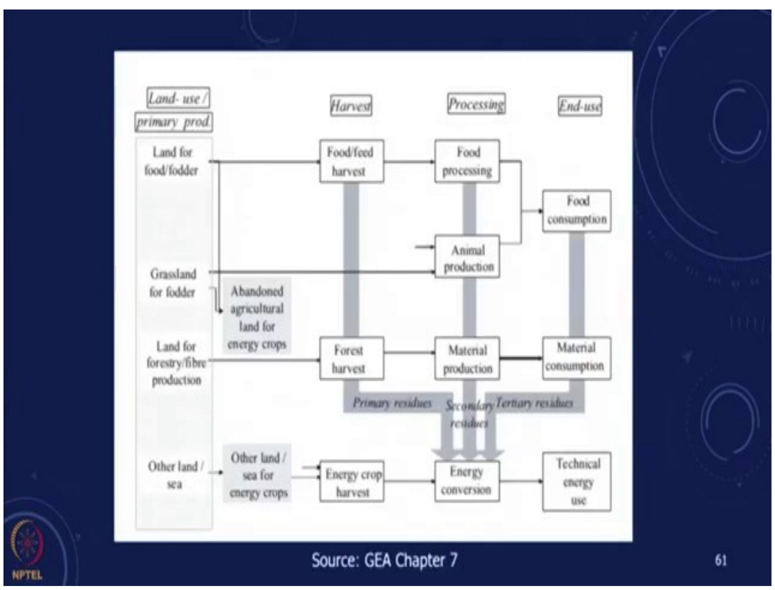

In the case of biomass, the issues is that if we want to dedicate some land for biomass production, if you want to dedicate some land for biomass production then there is an issue of food versus fuel and we can if we on the other hand if we just use the resources the waste which are coming from the animals or wastes which are coming from the harvest and then we can look at these has alternative use, then we can look at the surplus which is there for energy conversion and then look at the end use.

If we are doing dedicate plantation there is a fossil, there is a food versus fuel and that is a problem we need to see we also need to see if we are getting bio fuels what is the amount of energy that we are putting in, into creating that bio fuel. So, in a later lecture we will talk about net energy analysis and we will see how this looks.

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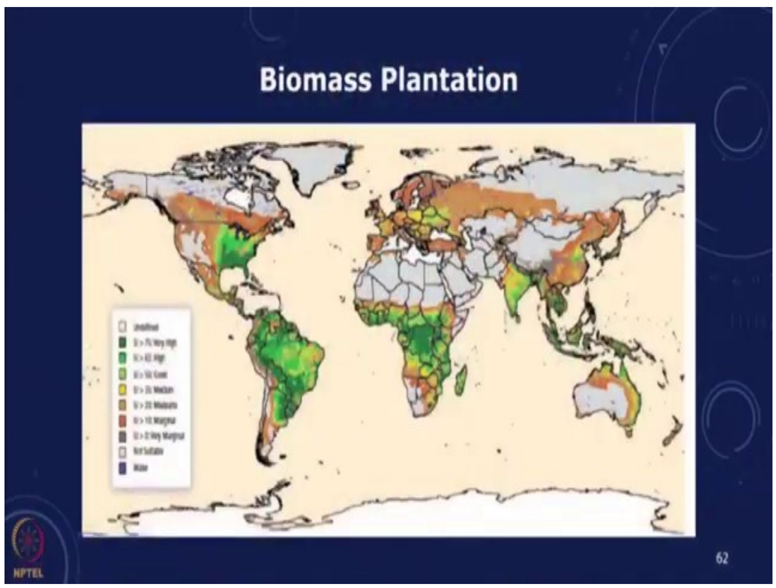

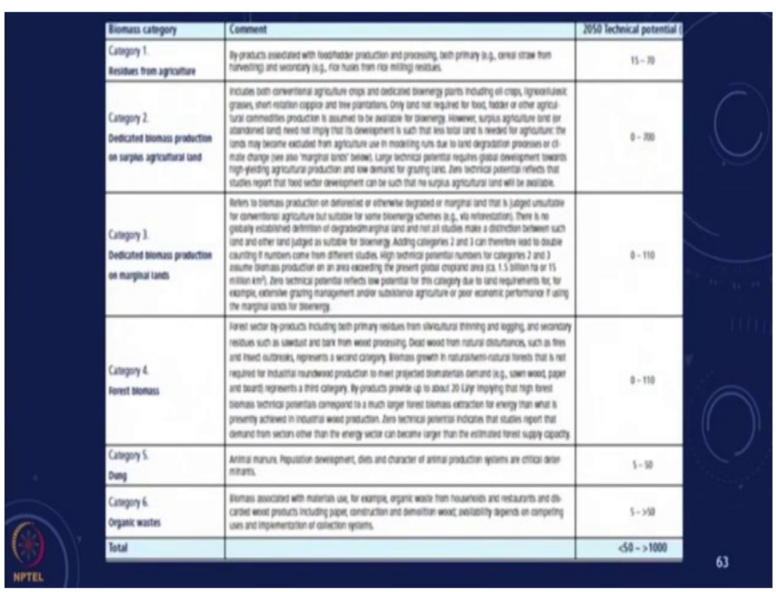

Biomass category	Comment	2050 Technical potential (
Category 1. **Residues from agriculture**	By-products associated with food/fodder production and processing, both primary (e.g., cereal straw from harvesting) and secondary (e.g., rice husks from rice milling) residues.	15 – 70
Category 2. **Dedicated biomass production on surplus agricultural land**	Includes both conventional agriculture crops and dedicated bioenergy plants including oil crops, lignocellulosic grasses, short rotation coppice and tree plantations. Only land not required for food, fodder or other agricultural commodities production is assumed to be available for bioenergy. However, surplus agriculture land (or abandoned land) need not imply that its development is such that less total land is needed for agriculture: the lands may become excluded from agriculture use in modelling runs due to land degradation processes or climate change (see also 'marginal lands' below). Large technical potential requires global development towards high-yielding agricultural production and low demand for grazing land. Zero technical potential reflects that studies report that food sector development can be such that no surplus agricultural land will be available.	0 – 700
Category 3. **Dedicated biomass production on marginal lands**	Refers to biomass production on deforested or otherwise degraded or marginal land that is judged unsuitable for conventional agriculture but suitable for some bioenergy schemes (e.g., via reforestation). There is no globally established definition of degraded/marginal land and not all studies make a distinction between such land and other land judged as suitable for bioenergy. Adding categories 2 and 3 can therefore lead to double counting if numbers come from different studies. High technical potential numbers for categories 2 and 3 assume biomass production on an area exceeding the present global cropland area (ca. 1.5 billion ha or 15 million km²). Zero technical potential reflects low potential for this category due to land requirements for, for example, extensive grazing management and/or subsistence agriculture or poor economic performance if using the marginal lands for bioenergy.	0 – 110
Category 4. **Forest biomass**	Forest sector by-products including both primary residues from silvicultural thinning and logging, and secondary residues such as sawdust and bark from wood processing. Dead wood from natural disturbances, such as fires and insect outbreaks, represents a second category. Biomass growth in natural/semi-natural forests that is not required for industrial roundwood production to meet projected biomaterials demand (e.g., sawn wood, paper and board) represents a third category. By-products provide up to about 20 EJ/yr implying that high forest biomass technical potentials correspond to a much larger forest biomass extraction for energy than what is presently achieved in industrial wood production. Zero technical potential indicates that studies report that demand from sectors other than the energy sector can become larger than the estimated forest supply capacity.	0 – 110
Category 5. **Dung**	Animal manure. Population development, diets and character of animal production systems are critical determinants.	5 – 50
Category 6. **Organic wastes**	Biomass associated with materials use, for example, organic waste from households and restaurants and discarded wood products including paper, construction and demolition wood; availability depends on competing uses and implementation of collection systems.	5 – >50
Total		<50 – >1000

So, when we look at biomass plantation, with the different kinds of fields this is the kind of yields which are available in different parts of the world and this has given this has again being classified in terms of a technical potential of biomass.

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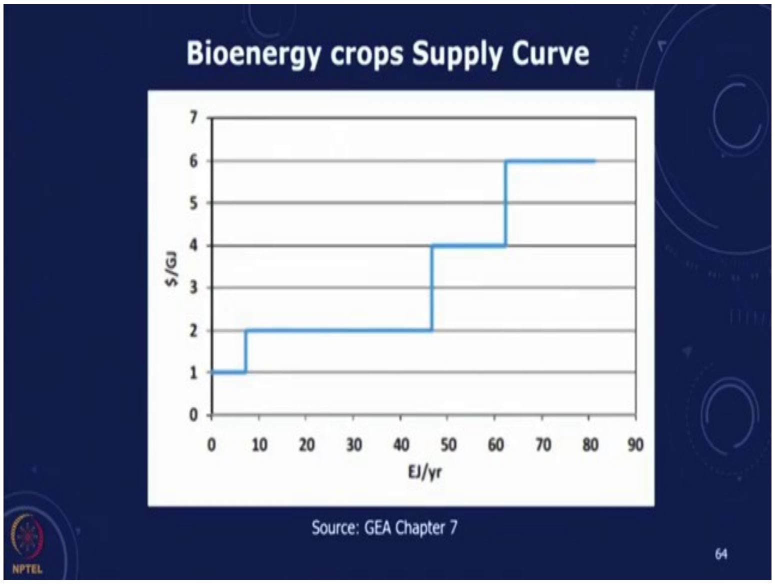

The problem in the case of biomass is that aggregation and creating a number for the country, a number for the world is a difficult exercise and its subject to many uncertainties, this is a local issue and we really need to identify locally the supply demand and the maps.

In the case, of bio energy this supply curve which is being drawn in the GEA if you see, this supply curve gives you at different we can go up to a 80 EJ/year at about 6 $/GJ. Biomass can be reasonably cost effective there is an issue of as we said the use of land, use of water and we have to look at it in terms of the sustainability but biomass bio energy systems have not being growing at the rate at which PV and wind have been growing.

Bio energy systems have the added advantage that most of the technology and most of the generates local employment and these are something where we think in the future that there will be much more in terms of potential.

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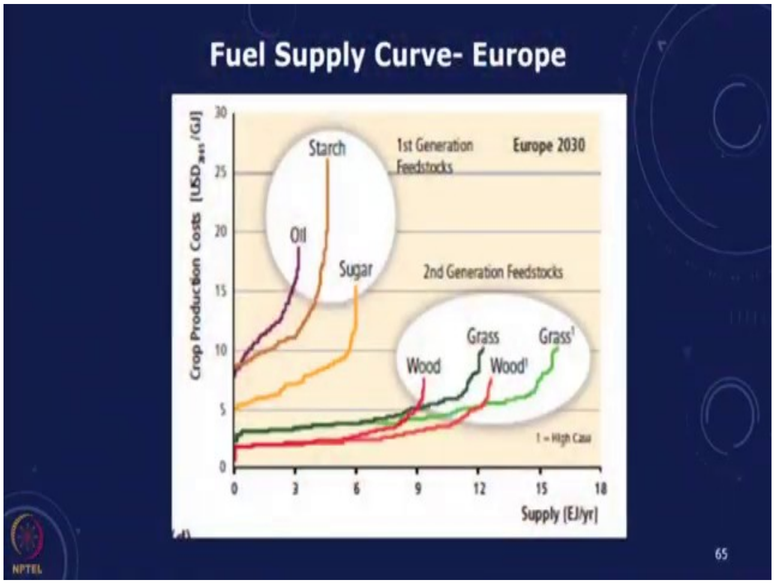

In Europe, there have been some estimates of the kind of form different kinds of there are again there are different technologies for conversion. The first generation, second generation and with genetic engineering we are looking at different kinds of conversion routes. In all of this we have to look at the overall sustainability in terms of energy as well as other issues in terms of land and water. But this is some of the things which is there.

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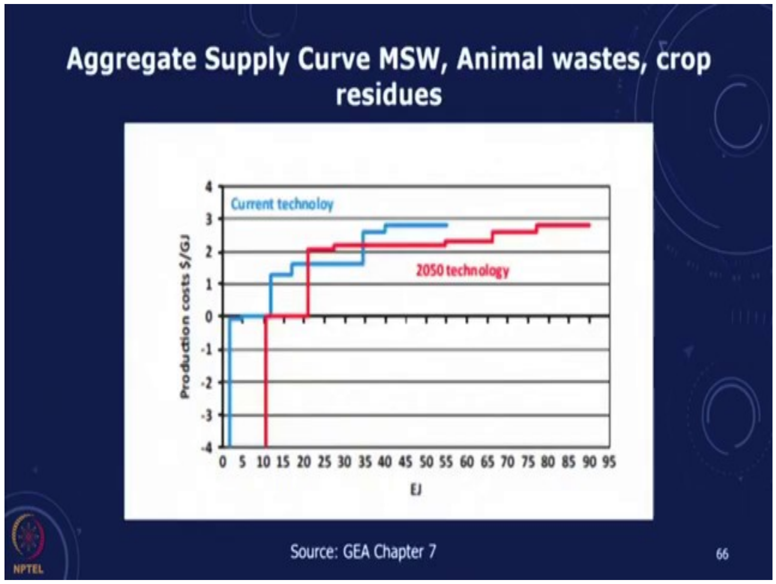

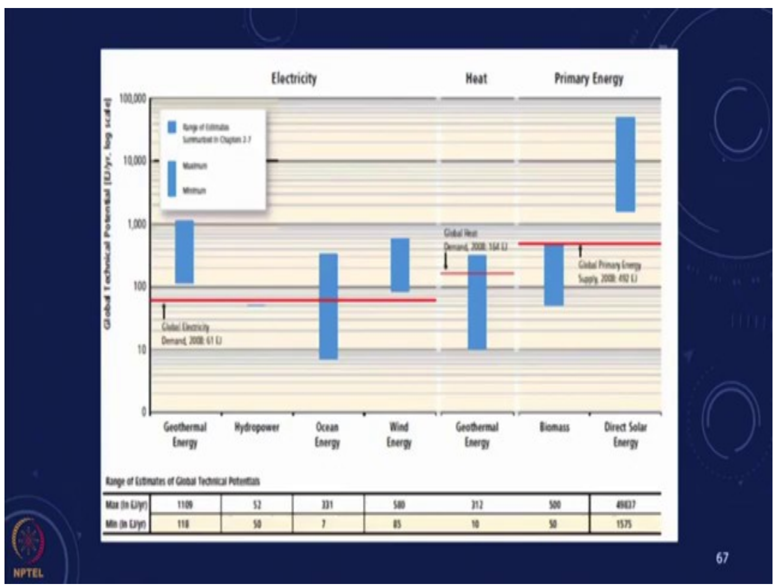

And this is an aggregate supply curve with municipal solid waste, animal waste, crop residues. So, if we combine all of this you can see the this is a image which is there from the global energy assessment which talks about electricity, heat and primary energy and talks about the exajoules available, we can clearly see that in the case of renewables we are not constraint by the potential, there is significant amount of potential, this may be distributed we have to see how and where we can do it in terms of cost effecting methods.

When you analyze any particular location, we can find out what are the local resources in terms of renewables whether it is solar or wind and then identify for the demand how much you can require, we can then look at the cost effectiveness of such things. Now one of the key things when we talk of renewables situation and when we are looking at large scale renewables is that we have to match the supply and the demand.

And matching the supply and the demand means that we will look at solar the solar supply is starting from let us say 6 o clock or 7 o clock in the morning and going up to 5 or 6 in the evening. When you are demand is in the night and we are looking at the commercial load and the lighting load coming in from 6 in the evening till about 10 or 11 in the night where we will have a high demand we need to then slower the energy which is coming in from solar and then use that energy in the night.

This involve an additional cost and the total amount of storage that we have installed for the energy sector is not even 1 percent of the total energy that we supply and this is also there are many different storage options and this is of course another topic.

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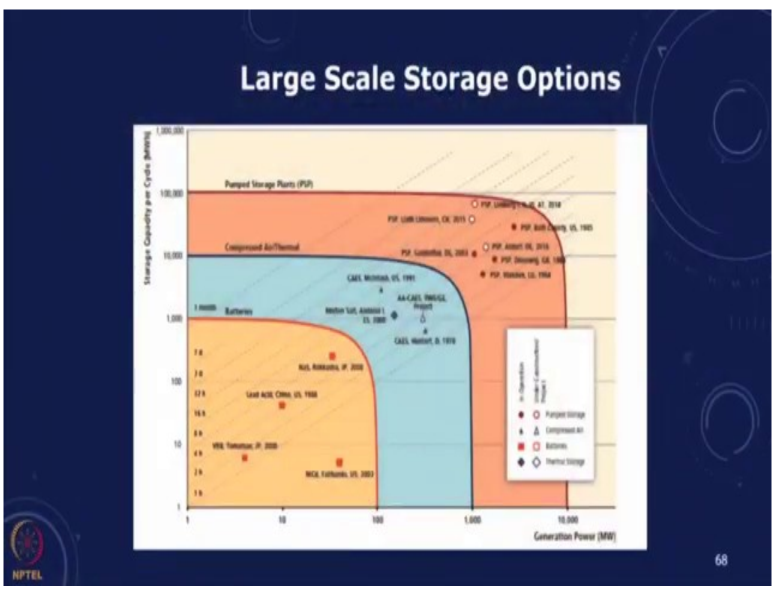

But when we look at you can look at the economics of different kinds of storage, it could be large scale storage it could be distributed storage and when we talk in terms of storage large scale storage it is mostly we are looking at you know today the most cost-effective large-scale storage is the pumped hydro.

Where we look at hydro having a low reservoir and a high reservoir and you pump the energy from the low reservoir to the high reservoir even that today, at today's price is that cost you another 5 rupees per kilo watt hour. So, this is going to be an issue when we talk in terms of high renewables. The matching of supply and demand we try to see so far in the electricity grid we were looking at thermal and hydro scheduling.

Now when you have renewables we have thermal, hydro, solar, wind scheduling mostly today in order to encourage renewables when we supply renewables we consider them as must run that means when the PV generates we try to use it, when the wind generates we try to use it, this will result as we saw in some cases in the backing down of thermal power. So, when we look at a future demand and we have high renewables.

What we do is we take that future demand subtract from it the renewable share and then see the net energy which has to be met by the fossil and this leads to what is known as that California duck curve, so we have to see whether or not the supply system is able to meet that and this involves, so at a system level when we talk of high renewable energy penetration we have to plan our systems differently.

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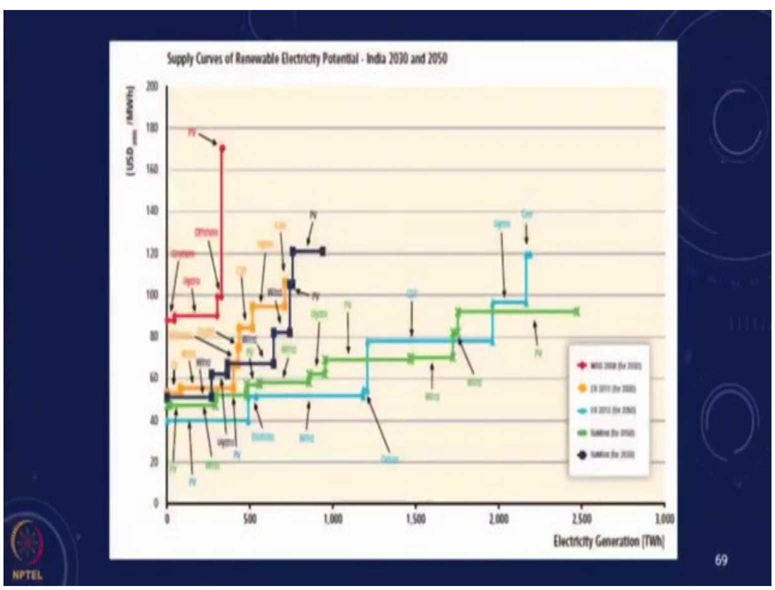

In the GEA, as well as in the special report on renewables, there are some supply curves given for renewables and you can look at this in a little bit more detail. So, to sum up we have looked at today we have looked at the different methods of assessing renewable energy resources, we saw these resources are distributed and depending on the type of resource we would map the distribution of the supply, we would also see how it would vary over the day and the season.

Whether it is wind, whether it is solar or it is the tidal OTEC or the biomass we have seen different ways to estimate and look at the potential. Today these renewables are relatively small but they are going to be an increasing part of our energy mix and when we look at a particular application we need to estimate what is the technical potential and the economic potential and then design our systems for that. With this we will close our chapter on renewables, we will also now look at what is the situation in terms of materials that we need for the renewable sector.