Energy Resources, Economics, and Sustainability

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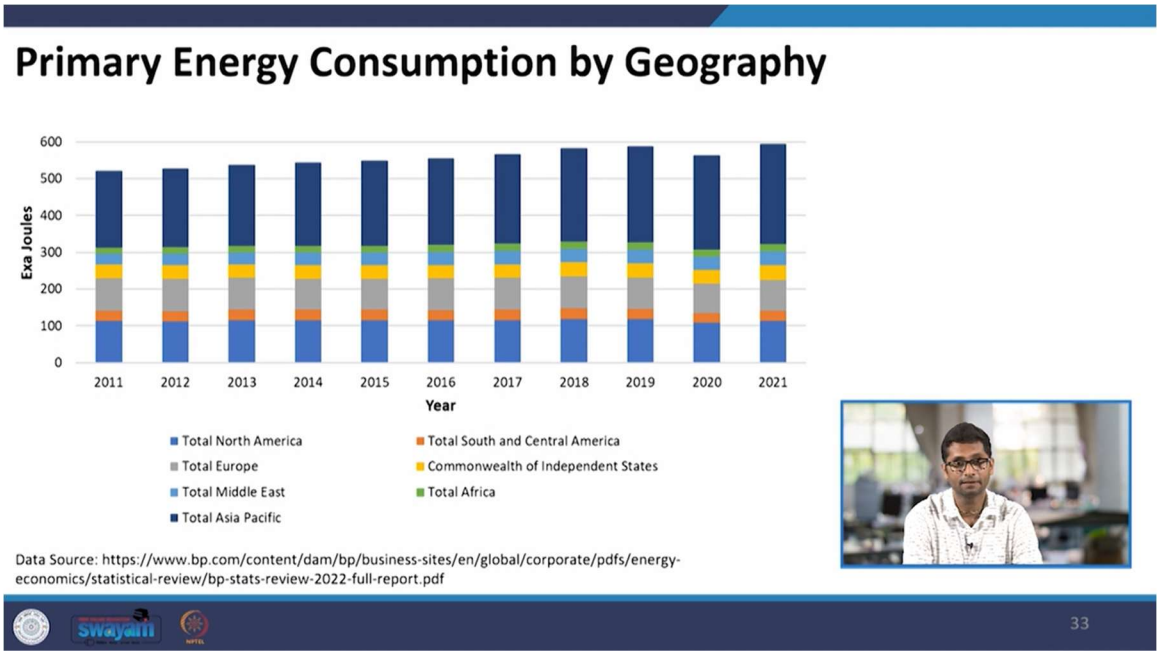
Week – 01

Lecture – 03

Lecture 03 - Introduction to Renewable Energy

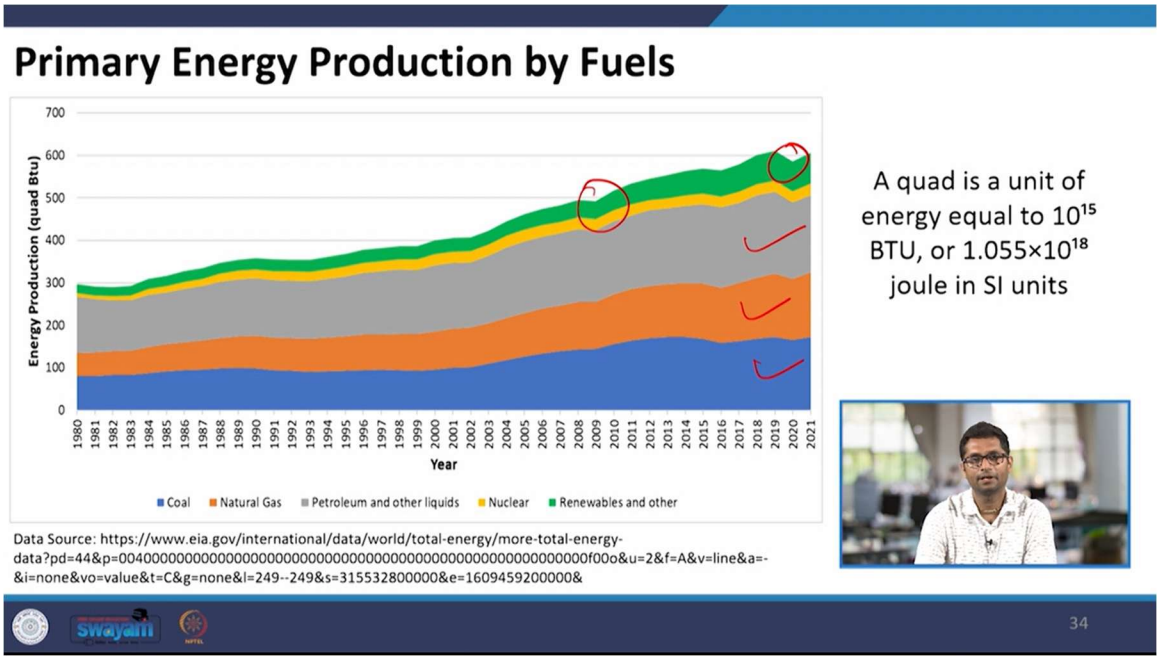
Hello everyone, welcome back to the course Energy Resources, Economics and Sustainability. In the last class we have been discussing the different issues related to conventional or fossil fuels. Today we will be carrying on the same discussion but jumping on to the so called renewable sources of energy. But before that let us try to start where we left in the last class. We were discussing this interesting infographic which shows us the correlation between GDP per capita as it grows and the energy use in terms of oil equivalents. We have in front of us different countries of the world, the major countries and we can see that there is a very nice correlation that exists between the growth of GDP and the energy use per capita.

We see all the developed world on the right hand side top corner, United States, much of the Europe, Australia, Canada and we see ourselves and our neighbours at the bottom left hand side corner. It is important to say that we have been embarking on a journey where we would want to increase the GDP per capita. In short, we would like to raise the standard of living of the normal person that stays in our country and in doing so it is imperative that we would also be increasing the energy use because both of them are very closely linked. Even if we look at the data from different sources, so this is the data with respect to the energy consumption by the different geographical entities.



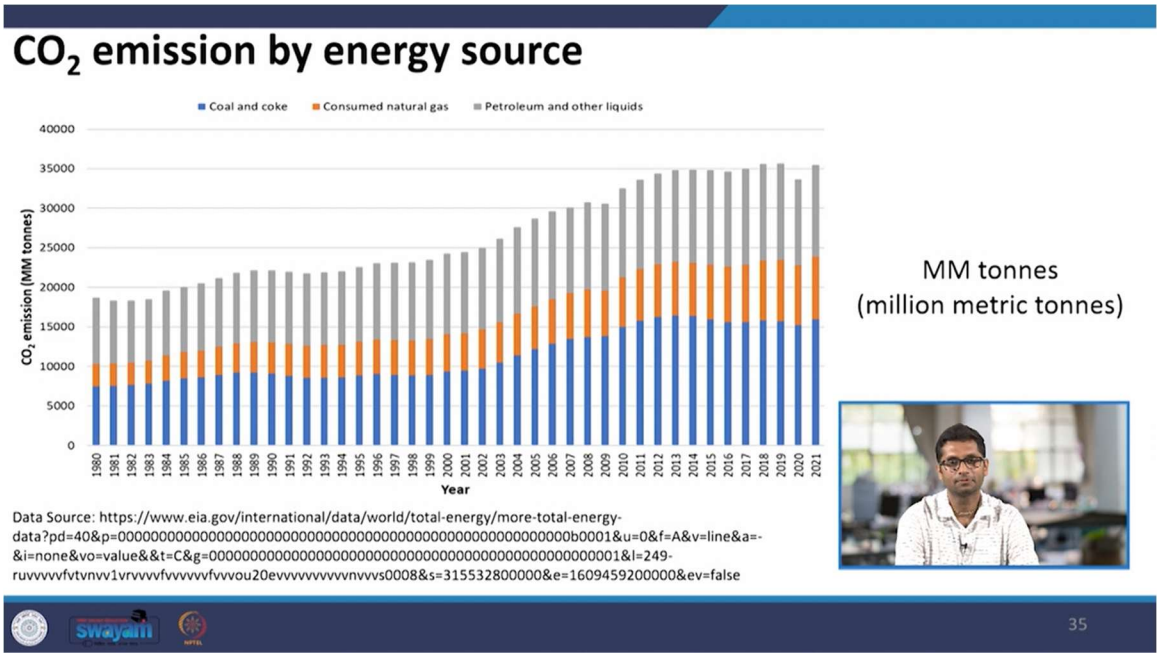
What we see here in the dark blue colour is the Asia Pacific which basically represents more than half of the earth's population and the energy consumption has been increasing. And this energy consumption is owed to the increase in the standard of living that is happening in our country as well as our neighbouring countries. We also see that other parts of the world, mainly the OECD world or the developed world represented by the North America and the Europe are almost stagnant or might be slightly decreasing. So there are two reasons for that. One is there are suggestions or there are actions that are being taking place for increasing the energy efficiency of these countries.

Further, some of these countries are also experiencing a decline in population. But nonetheless, we can see in our part of the world the population is increasing and so is the energy use. So, the energy use is something that will keep on increasing in the coming few years. And this increasing energy use is also nicely correlated in the increase in the use of conventional or fossil fuels. As we can see in this graph, the major providers of energy remain coal, natural gas and petroleum products.



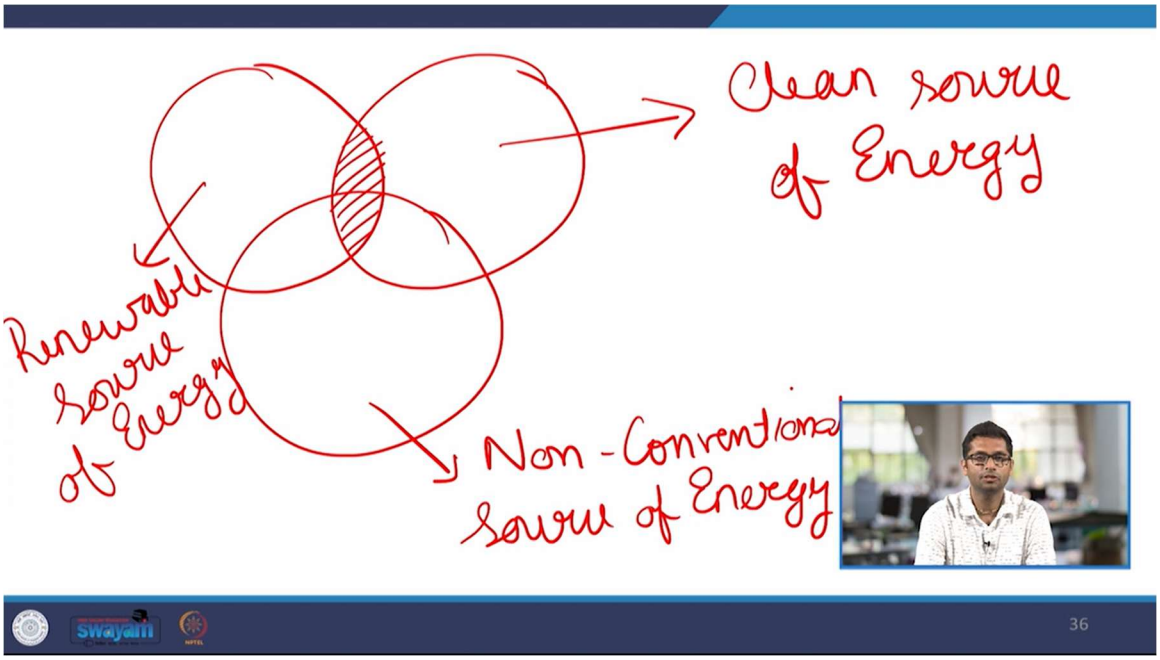
They provide more than 80% of the energy that would be used in different applications. We will be studying in the future classes how this energy is utilized in different applications, which might be industries, building sector, transportation sector, chemical sector and others. But nonetheless, what is important to understand that in spite of much of the popular notion about renewable energy, we are still majorly focused on fossil fuels for providing a major chunk of our energy and this keeps on increasing. You can see how it has been increasing from around 300 quads to almost 600 quads, almost doubling in the last 40 years or so. And one quad is basically equal to 10 to power 15 British thermal unit, which is equal to around 1 into 10 to power 18 joules.

We also see there have been ups and downs in this energy usage. We can see there is one kink happening at around 2020, which was basically due to the COVID coming in. Then another one can be noticed around 2008, which was because of the recession. One important thing to note here is like if you concern different sources like the IEA or the BP or the NITI AAYOG, this data would be slightly up and down. But what is important to study is a trend and this trend is in agreement in almost all of the reports.



Further, this increase in energy consumption that is predominantly based on fossil fuels is also nicely correlated to the CO2 emissions. So, if you look at the CO2 emissions, which could be attributed to these three main fossil fuels, which is natural gas, coal and petroleum, it has kept on increasing in the last 40 years or so. The majority of it can be owed to coal based production of energy, which is basically termed as dirty energy and also leads to release of maximum amount of CO2 into the atmosphere. But we also have the natural gas and the petroleum playing their role equally well. Now, these all issues related to conventional or fossil fuels lead us to going towards renewable source of energy or sustainable source of energy, clean source of energy, non-conventional source of energy.

So, before jumping into understanding what are the sources of energy, let us try to understand the definition. Now, in popular literature or different books, you would be coming across these different words like renewable source of energy, clean source of energy, non-conventional source of energy. Does these all mean the same thing or they are different? So, let us first try to understand the definition. We can help this understand this with the help of a pie diagram. So, one thing could be clean source of energy, then there could be non-conventional source of energy and then there could be also renewable source of energy.



So, when I say the term clean source of energy, what I mean is the source of energy does not have any adverse effect on the atmosphere. It is renewable or non-renewable is none of my concern. The underlying factor is it should not have a very drastic effect on the environment and based upon what the effect we are considering, there could be one source could be clean and the other could be unclean. Then coming to the definition of renewable source of energy, a source of energy that has the ability to renew itself in a fairly short amount of time is called renewable source of energy. Now, there could be a renewable source of energy that is not clean in nature.

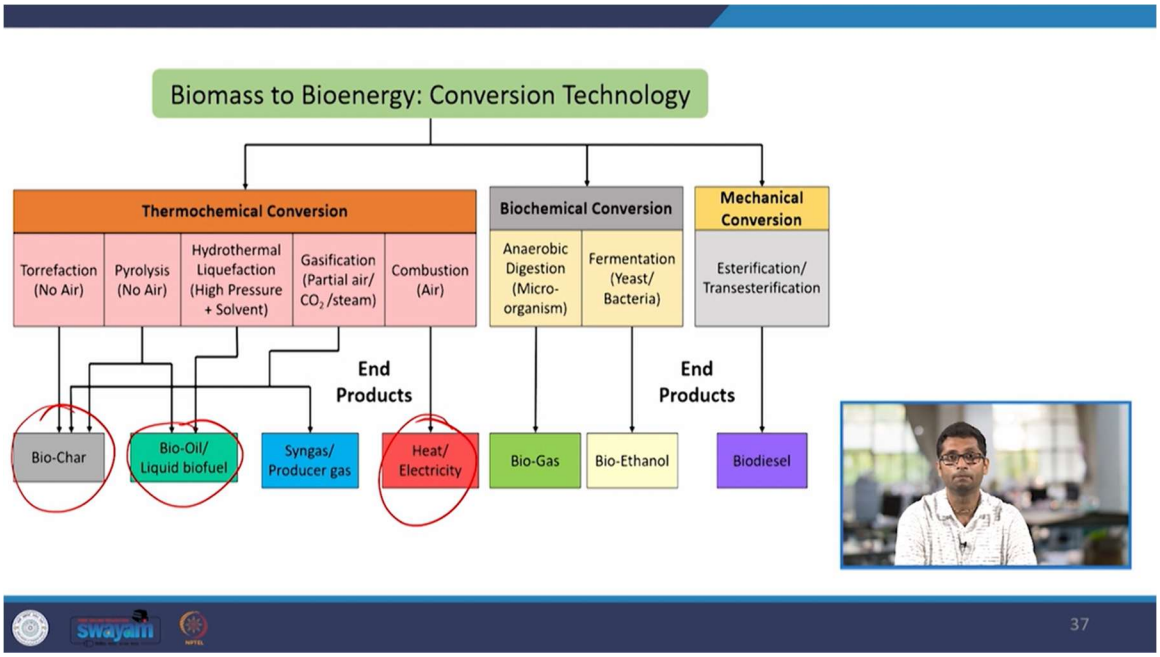
An example could be biomass. If you are burning biomass, you would be releasing CO2 in atmosphere. It has advantage that biomass can be renewed, but if it is clean or not, it is something that is questionable because it also releases CO2 into the atmosphere. Then comes the term non-conventional source of energy. Now, non-conventional source of energy basically depends upon what is used in majority and today's world if I say coal, gas and petroleum are considered conventional source of energy because majority of energy is attributed to these resources.

If I go back 300 years or more, a majority of the power or energy that we were using was coming from biomass. In that time, biomass was a conventional source of energy. If we move into the future, solar might be a dominant source of power and that might be called

a conventional source of energy. So, when I talk about conventional or non-conventional source of energy, this is basically to do with what is used in majority. It is not much attributed to what is clean or not or what it is renewable or not.

So, as far as our understanding is concerned, what we should be interested in is a source of energy that is clean in nature as well as renewable in nature. So, we should be concentrating is this particular intersection of the sources of energy which are clean, which does not affect the environment in a drastic manner and also have the ability to renew itself in a fairly short amount of time. It should not happen that the reserves are depleting and because of the depleting reserves, there are fluctuations in the prices. Whether the source of energy is conventional or non-conventional that is just a matter of time. Something that was conventional few hundred years back might become non-conventional today and something that is conventional today might become non-conventional in the coming centuries or so.

So, that should not be our concern. What we should be more concerned about is the source of energy should be clean in nature, it should not have any drastic effect on the environment and also it should have the ability to renew itself in a fairly short amount of time. Now, let us proceed further to understand what are the major sources of energy which could be attributed to both renewable and clean.



So, the first source of energy that we would come across is biomass. Now, biomass is known to mankind as one of the earliest source of energy. If you even go to the traditional areas or the countryside people are using wood logs or cow dung for cooking purposes and other different heating purposes. So, that is what we meant by biomass. We have been using biomass since centuries as a source of heat and this continues till date. But in the present time we also have many technologies which could convert biomass into different forms of energy in a fairly efficient and clean manner. Among them would be thermochemical processes, biochemical processes and chemical or mechanical processes.

I will just give you a brief overview of what these processes are. So, if I talk about thermochemical processes, this basically involves utilization of thermal heat and chemical aspects of biomass to produce different value-added products. I can heat the biomass in an insufficient supply of air and produce charcoal or coal like substance which could be termed as biochar and this biochar could be used as a fuel or it could also be used as a soil enhancer. Then we could also have processes which are occurring at very high temperatures and pressures something like hydrothermal liquefaction. The typical operating conditions are around 350 degree Celsius and 200 bars.

What I get in return is bio oil or bio crude which in turn could be theoretically refined and can lead to production of naphtha grade or gasoline grade or diesel grade fuels. Similar thing could also be accomplished by pyrolysis which is heating of the biomass in no supply of air and what this results in two products it is the bio oil, biochar as well as the gas. The major products remains bio oil and biochar and based upon the heating rate you can control if you want to produce more oil or more char. Then we also have process called gasification which means you are heating biomass in an insufficient supply of air which means you provide some oxidizing agent but that is not enough to combust the biomass fully. What you get in return is a gas called synthesis gas or producer gas which has a calorific value and could be used for running engines or heating applications.

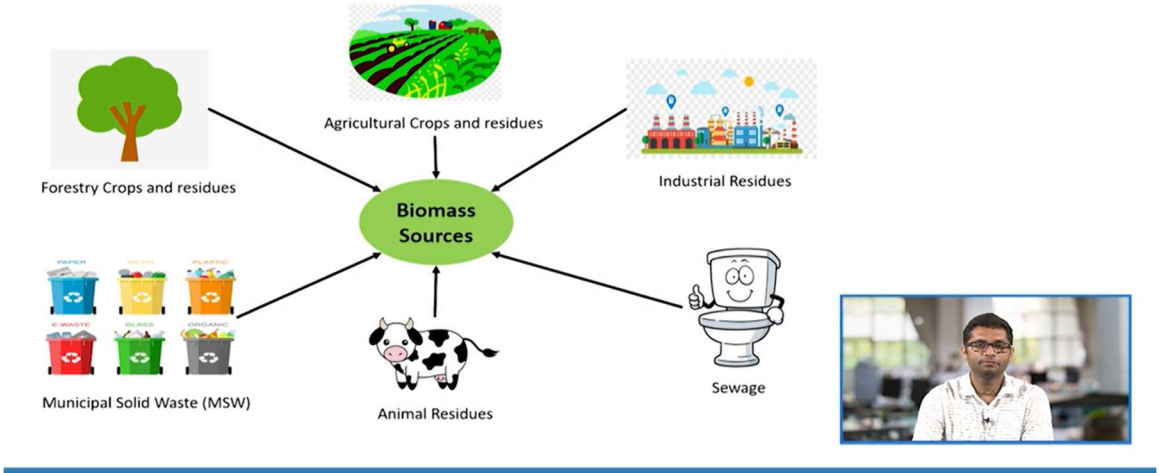
You might be surprised to know that if you go back 60 years or 70 years back during the World War II we had many cars running on biomass gasifier based syngas. We had a gasifier attached to the back of a cars and the cars running on this. It was also called

wood gas back that time. There could be an application called combustion where you are just combusting biomass producing heat this could be used for heating applications you could also restream and this could be used for production of electricity. Then coming to the biochemical conversion pathways.

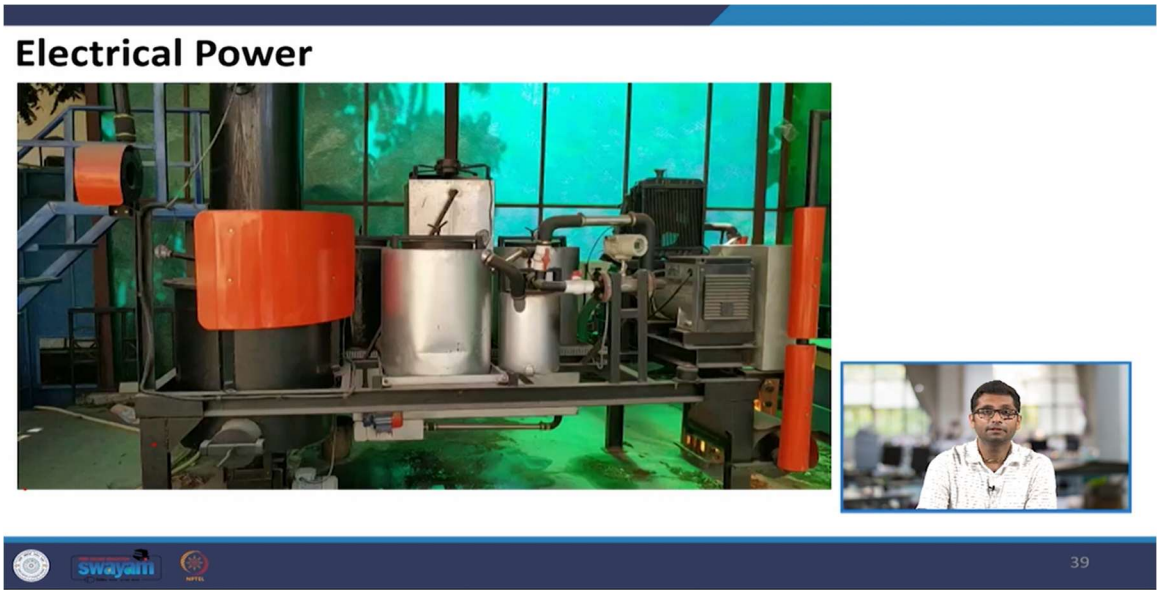
In biochemical you apply a bit of microbes which have their role to play. The most basic kind of biological process would be anaerobic digestion. We all know it by the name of gobar gas or biogas. We have different kinds of food stuffs which are waste which could be associated with different microorganisms. The microorganisms eat up and produce a gas that is rich in methane CH4 and CO2.

This methane provides a calorific value to the gas and this gas could then be used for different heating applications. And now as for the different schemes that have been came up with the government it is also used for production of compressed biogas which is used as a replacement of CNG and also for different industrial applications. The biomass could also be converted into ethanol with the help of different fermentation techniques. Again this is used for lignocellulosic biomass and the ethanol produced could be used for increasing the quantity of bioethanol in the petroleum products that you use in your vehicles. Another pathway would be the production of biodiesel and this pathway is called transesterification which means you extract oil from the different plants that are rich in oils, convert that into a fatty acid methyl esters and these esters can then be used as a replacement of diesel in your vehicles.

So as you can see biomass is a source of energy can provide you both solid fuels in the terms of biochar, biocoal, gaseous fuels in terms of synthesis gas or biogas and liquid fuels in terms of bio oil or bioethanol or biodiesel. Then comes what are the different sources of biomass again the biomass could come from agricultural residues which are huge in India. India being an agricultural country has huge reserves of agricultural residues. One major residue being rice straw which is a problem then there could be forestry crops and residues an example could be pine needles which is again a menace in the state of Uttarakhand and Himachal. There could be industrial residues in terms of bagasse that you get from the sugar refineries.



There could be waste coming from the municipal solid waste. There could be animal residues in terms of cow dung or cow manure plus we also have the sewage sludge that is getting produced from wastewater treatment plants. All this comes under the bigger domain of biomass and we as a country have a huge population and because of this population we have huge sources of waste coming from different sectors and all this can be effectively utilized for conversion into energy.



Just giving an example so this is a typical gasifier which is used to convert different kinds of biomass into electricity. You can find these kinds of the gasifiers in operation in the state of Uttarakhand where you have the biomass feeding from the top and we would have electricity generating at the lower hand side corner. So what you see here is the gasifier in operation you would feed the biomass from the top and you could see that electricity is being generated so this is a standalone system where the electricity is being generated just by depending on the different biomass feedstocks.

Source: https://www.iflscience.com/environment/urban-algae-farm-gobbles-highway-air-pollution/

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Another typical example for biomass energy could be the green greenish kind that you see in the ponds it is also called as algae and it is gaining a lot of momentum in the developed part of the world where algae is grown in specific reactors called photobioreactors something like this and these algae are quite rich in fatty acids and which could be extracted and for production of different kinds of fuels or speciality chemicals downstream.

The technology has been validated and demonstrated at India Glycols Limited, Kashipur, Uttrakhand, India.

Capacity: 10 ton/day,
Product: 2G-Ethanol, 2G-Sugar, lignin

Plant name	Type D/C	Status	Start-up year	Biomass type	Feedstock capacity	Product	By product	Hours in operation
2G-Ethanol plant at India Glycols Ltd	D	Operating	March 2016	Any feedstock	10 ton/day	Ethanol (750,000 L per annum)	Lignin	4000h
HPCL, Bhatinda plant, Punjab	C	Under Construction	Expected 2020	Proposed for Rice straw, cotton stalk	450 ton/day	Ethanol (100 KL)	Silica, Food grade carbon dioxide, inorganic mineral fertilizer	
BPCL, Bina, Madhya Pradesh	C	In process for finalizing BEDP	Expected 2021	Proposed plant for wheat straw and soya	450 ton/day	Ethanol (100KL per day)	Food grade carbon dioxide, inorganic mineral fertilizer	

Source: http://artfuelsforum.eu/wp-content/uploads/2019/04/Booklet-on-technologies-presented-at-the-2nd-EU-India-Conference-on-Advanced-Biofuels.pdf

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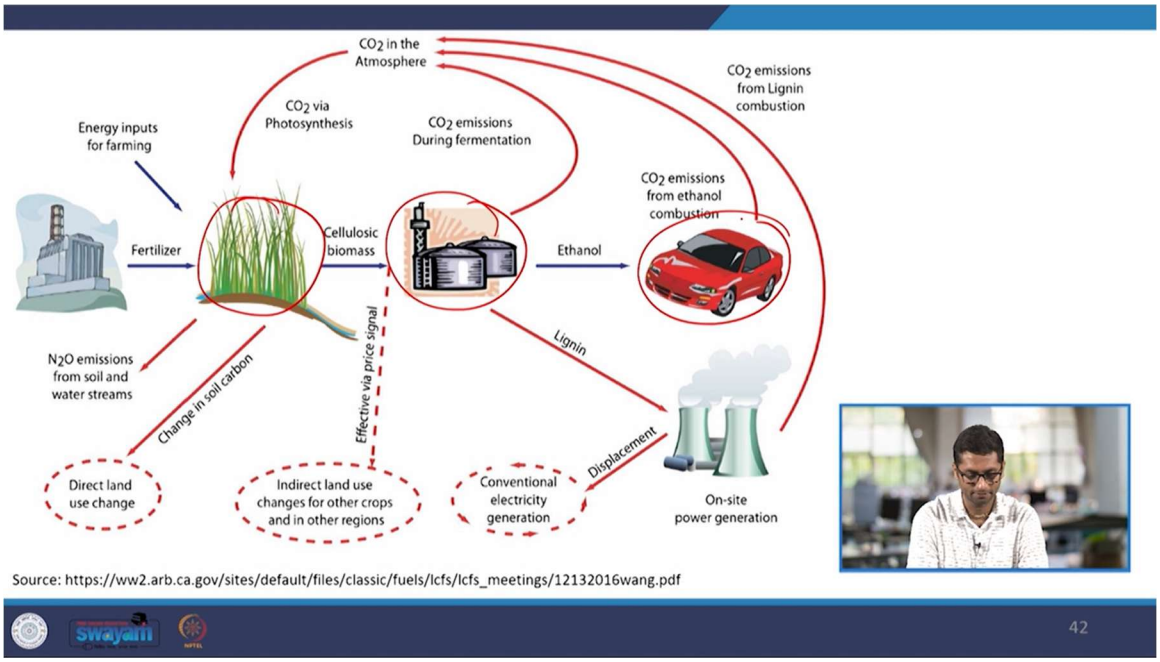
Here is another example of a biorefinery that was set up in the state of Uttarakhand in Kashipur that was for the production of bioethanol and so if anyone of you are interested you can plan a visit here which is also producing bioethanol from different kinds of biomass feedstocks.



But a major problem with the biomass is that as I have iterated earlier as well the combustion of any fuel coming from biomass would also release carbon dioxide upon its combustion. So if I look at the life cycle of a biomass you would have the growth of the biomass you would have the conversion process it could be any conversion process and then there could be use so here I have taken as ethanol being used in a car the combustion would lead to the production of CO2 in the atmosphere. Now this CO2 needs to be taken up back by the growth of more biomass so if this growth of biomass is not happening in a cyclic manner even biomass could be termed as a non-renewable source of energy or it could not be termed as a clean source of energy because we are not cycling back CO2 into the atmosphere. Further it is also important to understand what are different emissions throughout the life cycle of a particular fuel and this is something that we will try to understand in the life cycle assessment which we study towards the end of the course. Now another major source of energy would be hydropower. Hydropower the concept we all understand is the process of converting the potential energy stored in the water into the kinetic energy of the running water running turbines and which could be producing electricity. So normally you would have a water source that is located at a particular height it would be releasing water you would have turbines running and that would be producing electricity.

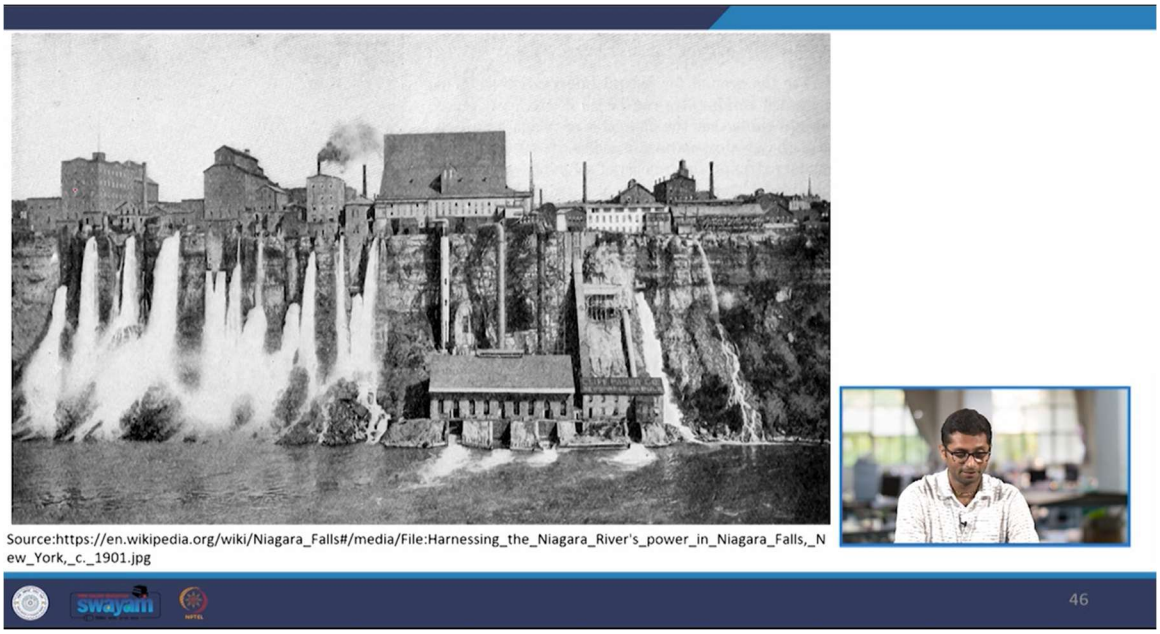
Source: https://www.britannica.com/topic/Three-Gorges-Dam

Now these dams could be very huge in size the example that you see in front of you is the three gorges dam in China this is probably the largest man-made water body that you have and it has also been predicted that this particular water body is responsible for slowing the pace of the rotation of earth by a few microseconds. So there could be huge dams like this and there could be also very small dams that we have in the Himalayan hilly regions.

Source: https://mnre.gov.in/small-hydro-0

Source: https://gfycat.com/imaginativegleamingaustralianshelduck

So you could have pico-hydro or micro hydro dams which could be used for producing small amount of electricity or even for crushing grains and producing different kinds of flours. The typical capacity of a plant like this could be a few kilowatt. Then a major issue with hydropower which we all see as a matter of debate is the effect on ecology.

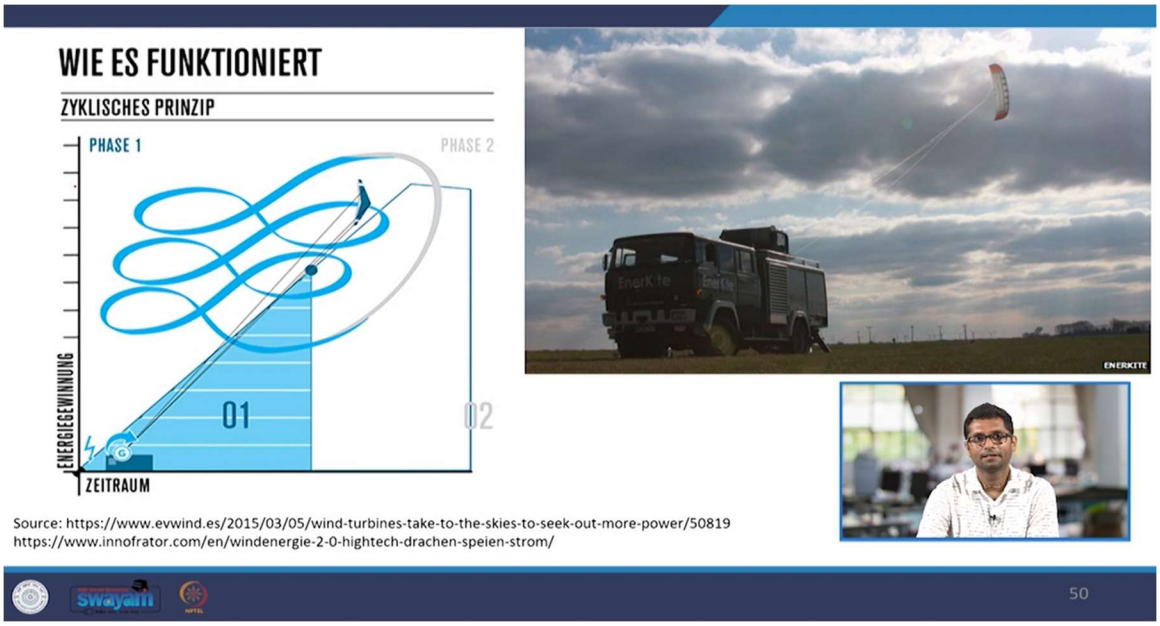


What you see in front of you is the famous Niagara falls in the US and Canada and how they looked like when the hydropower was used was produced initially at that falls. So it had a serious consequence in the ecology that is near these dams.

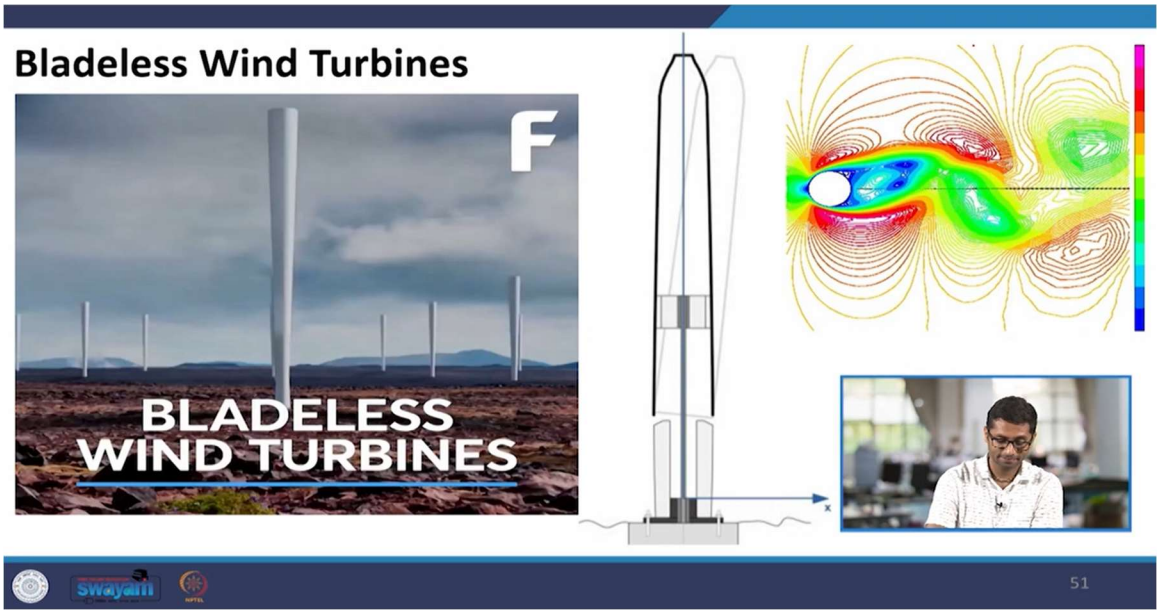
Then another major source of energy could be wind power we could have big big windmills producing electricity and this electricity would be clean in nature because it would not release any harmful gases into the atmosphere. So the figure that you see in front of you is from Jaisalmer where we have a large wind farm and you can see the sheer size of the wind farms. A major issue that people have reported is the loss of or the effect that it has on the aerial life which means the bird that hits these windmills and leads to loss of life and morbidity in this species.

You could also have this mills in the oceans the example that you see is the London array in the United Kingdom where you have big streams of windmills being installed in the oceans which are used to generate good amount of power.

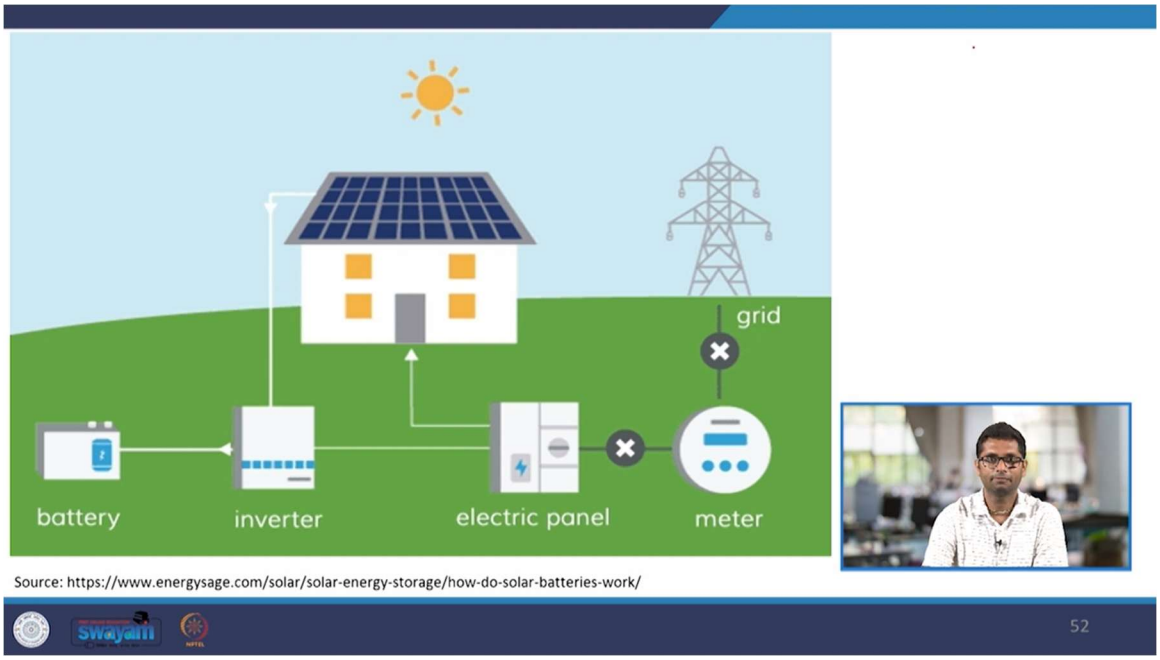
Now these windmills could also be smaller in size a typical example is something that you see in front of you. So this is an example of a wind tree where you have the small turbines being placed on an artificial tree looking almost similar to a natural tree but it is not. So this typical tree if there is good amount of air present could produce almost four or five kilowatt hour of energy which is good enough to power a house and these were the trees that were installed in front of COP21 when the meeting happened in Paris. Another example in the field of wind energy could be airborne wind energy wherein you have these portable devices and you have this kite like thing that is flown in a known trajectory and it helps to run the turbine which is coupled with the turbine and produce electricity.



So we know that larger wind speeds are available at greater heights and to reach these heights the people have devised this portable source of energy where you would have this truck which would be coupled or having a small turbine and this is a small parachute or a kite which would be flown in a known trajectory quite similar to us flying kites if anyone of you have flown kites in the childhood this is very similar to that and this is a portable source of electricity production.

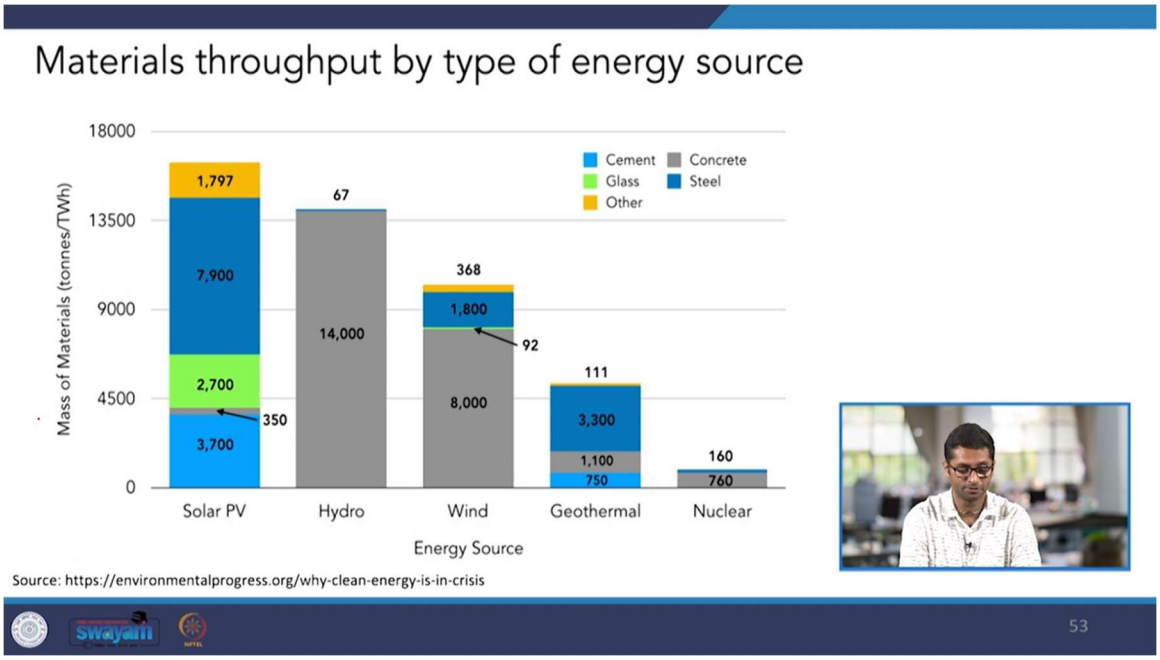


Another technology that is upcoming in terms of wind energy are the bladelessless wind turbines where the we do not have any wings because these wings normally have an adverse effect on the aerial life the bird hits or the death of the different species of birds it would consist of simple sticks which are vibrating because of the effect of rain and because of the vortices that are created small amount of energy could be generated.

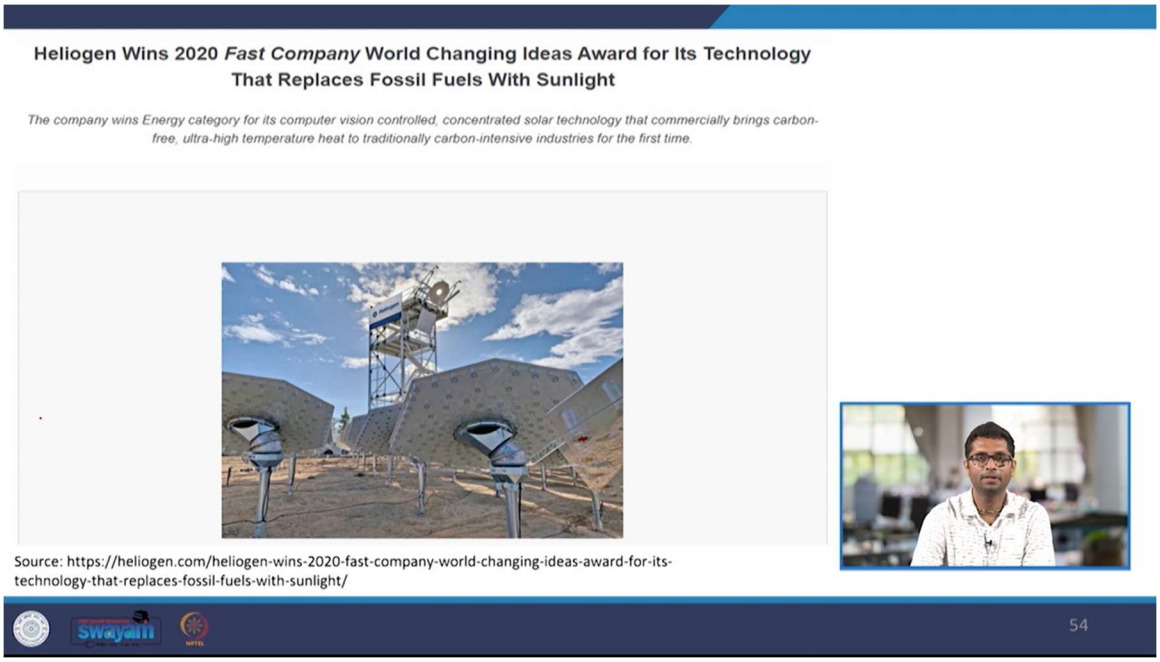


Then we also have the solar energy I believe we all know about solar energy if we go to any place in the country we can easily locate the different kinds of solar panels located on

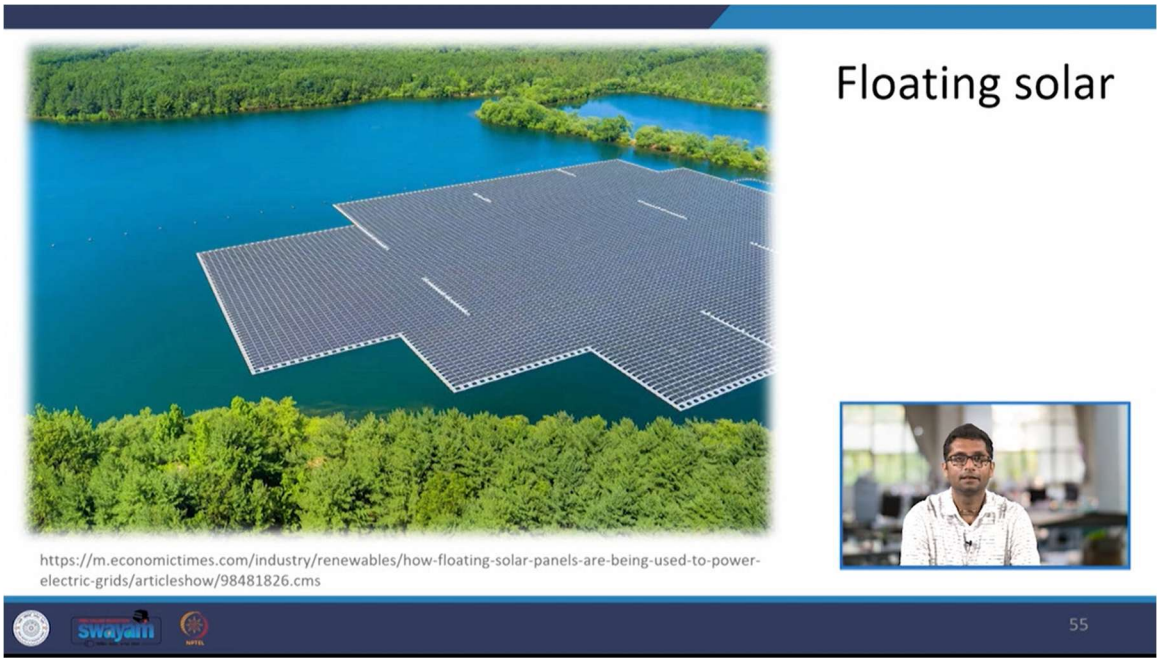
the rooftops which are used to produce electricity so in the daytime the electricity could be produced the extra electricity could be stored in a battery and the same could be utilized in the night time and also could be sent back to the grid if you have like if the grid allows you to do so. So this is one of the major sources of energy that are expected to play a major role as we go into the future but one of the major issues that relate to the solar energy is the large amount of material that goes into the production of the solar cells or the solar panels. So there have been studies quantifying this and it has been highlighted that the amount of material that goes into the production of per kilowatt hour of energy from a solar panel could be very high and disposal of these panels after the typical lifespan of maybe 15 to 20 years is again a big challenge people have been working on the recycling of solar PV panels extracting of silicon back and there have been different challenges that are associated with it.



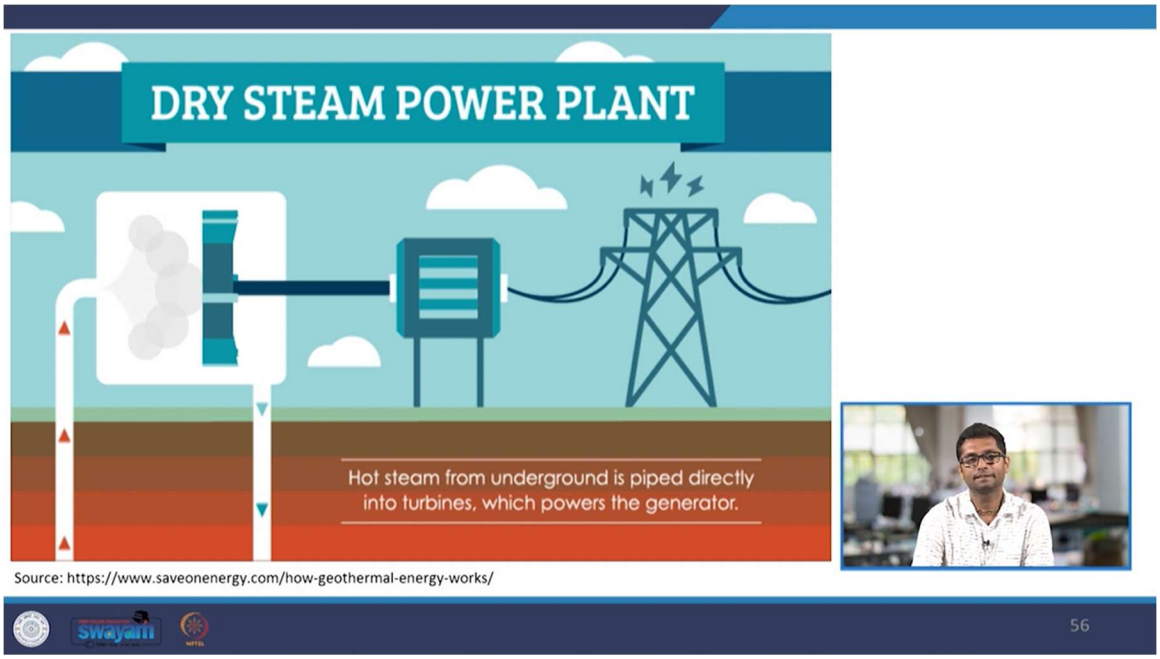
Plus a majority of the supply chain of these panels are in different countries and India is importing them so it should not happen that in the future we are reducing our reliance on fossil fuels but increasing our reliance on other types of panels which are used for producing of solar energy.



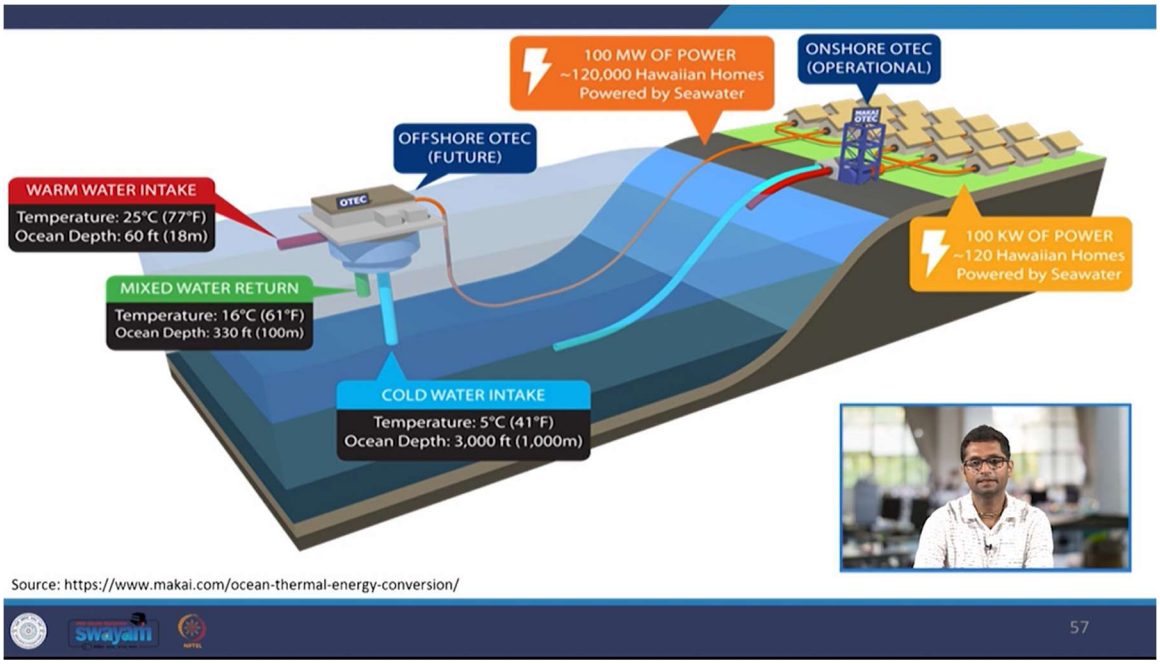
Some of the advancement that goes into the field of solar energy is a combination of artificial intelligence so this what you see in front of you are considered solar panels so these are not solar PV but sort of mirrors that reflect solar light and all the reflections are concentrated at this particular point which is used to raise temperature. So earlier known experiments had a limitation of raising the temperature only to a certain extent but because of the use of artificial intelligence and the increase in the knowledge in the field of computer vision we can now control the efficiency of this reflection and these kinds of panels are now generating energy or raising the temperature to up till 800 to 1000 degree Celsius which up till now was not possible. What is so great about it? The good thing is that most of the process industries have processes that work in this range 800 degree Celsius or 1000 degree Celsius so if you are able to raise the temperature up till this temperature range you can effectively utilize solar energy or green energy for powering these processes which up till now was not efficient in terms of electrical heating and what I give here is an example of a company called Heliogen which is fast progressing in this field it is based in the US and they are developing these solar panels for production of green hydrogen in the future.



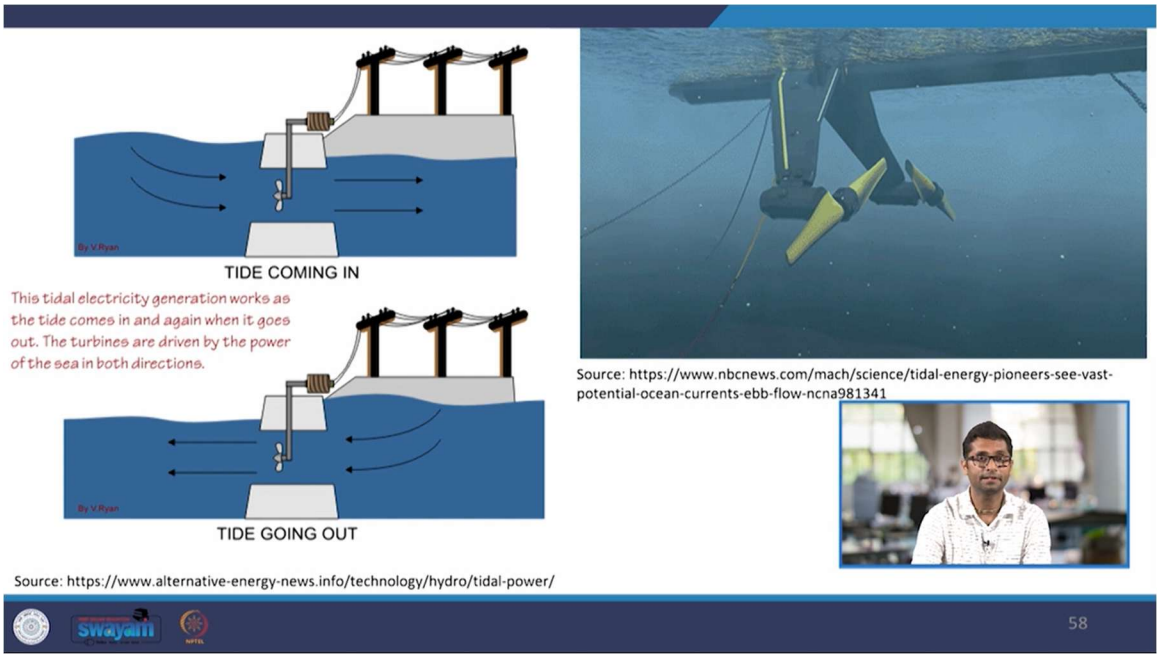
People are also looking towards going in the field of floating solar we have huge water bodies and these water bodies have huge amount of evaporation of water as well. Can we place solar panels that are floating in these water bodies? The advantage are two front one thing is we can utilize the area they are not consuming the precious land second thing is because of the water body being covered by a particular substance the evaporation of that particular water body is reduced. So floating solar is something is another technology that is gaining momentum in a big way we have companies like Ocean Sun which is a Norway based company and developing good amount of floating solar and there are many places in India where a lot of place where there are a lot of installation of floating solar as well.



Then another kind of technology could be geothermal energy this type of energy is becomes important only if you have restored with this kind of energy by nature not every country has many sources of geothermal energy one particular country which has a lot amount of geothermal energy is Iceland where almost 90% of the houses are heated with the help of geothermal energy that is available there. In India this energy is not available in a very large extent but the basic principle is that you would have the natural sources of steam and these sources of steam could be used for running of turbines and in production of electricity. Another source of energy could be OTEC which is ocean thermal energy conversion this particular type of energy basically makes use of the differential temperature in the different layers of ocean.

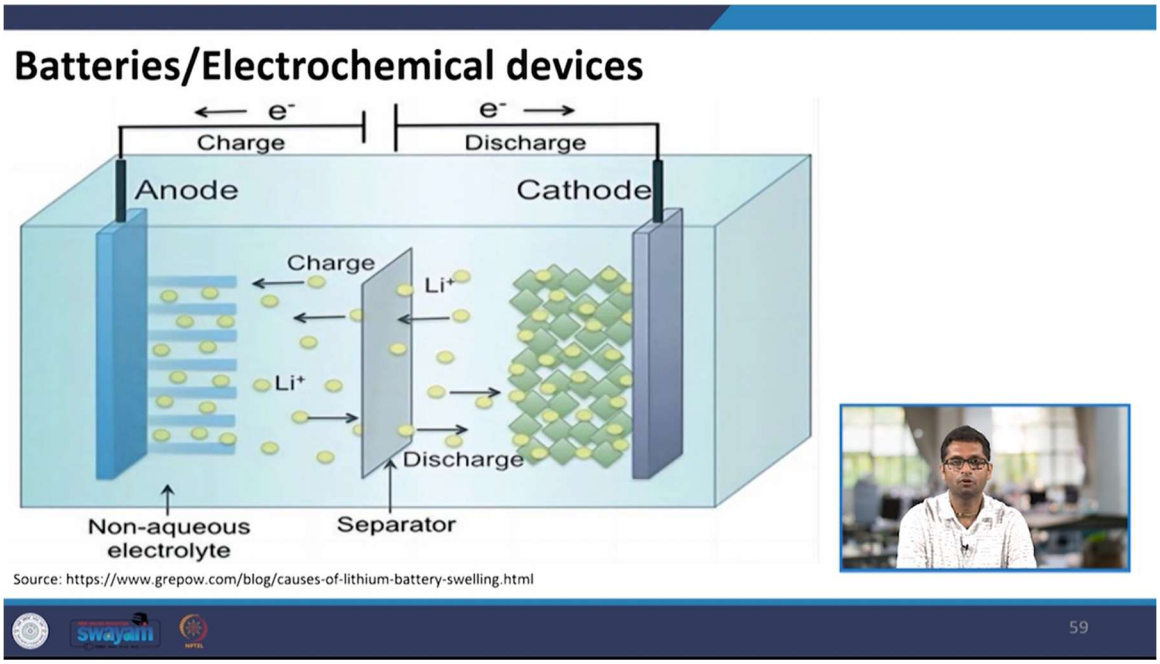


So the temperature of the water is higher at the top of the water body and becomes lower as we go into the depths of the water and this particular technology basically makes use of that differential temperature and has different types of heat exchangers running on different types of material and producing electricity.



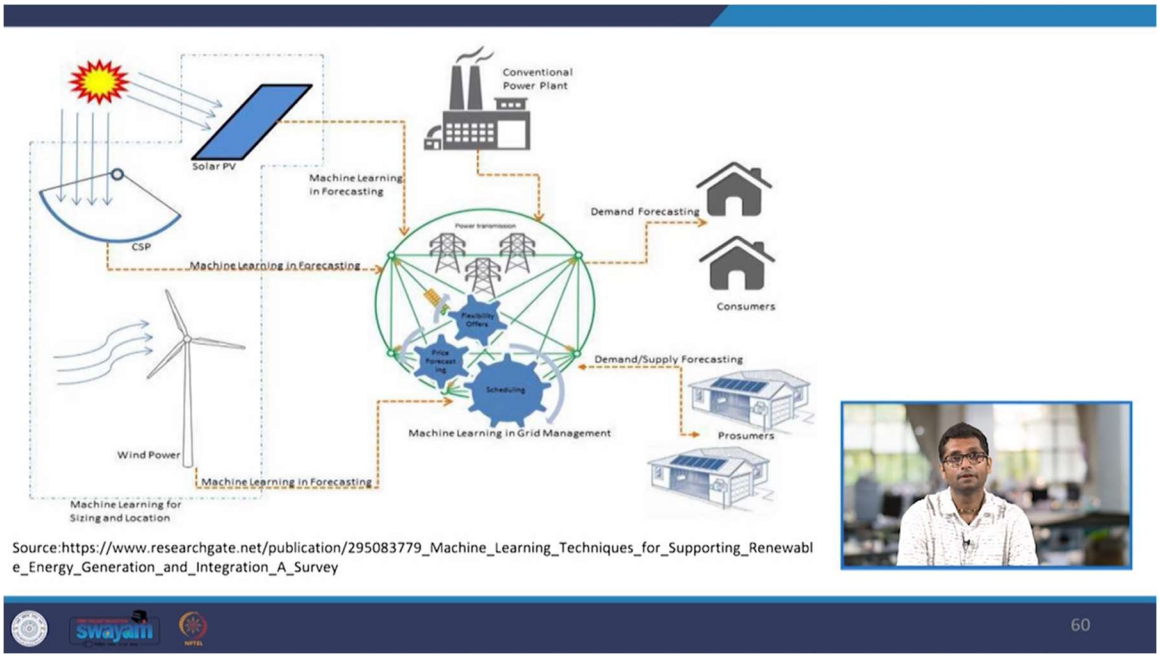
Another example could be tidal energy where you are making use of this tidal effects which is the increase and decrease in the level of ocean in the different times of the day

and this is again used to run turbines and producing electricity again you need to be bestowed with a natural bodies which could make use of phenomena like this. In India again we have limited quantity or limited places where this kind of technology could be applied plus we also need to understand that majority of renewable source of energy are variable in nature or are intermittent in nature. You talk about the major sources wind and solar they are not available throughout the day. So what happens when the electricity demand is more when the sources of energy are not available you need to store this energy and use it and for this the energy storage also becomes important.

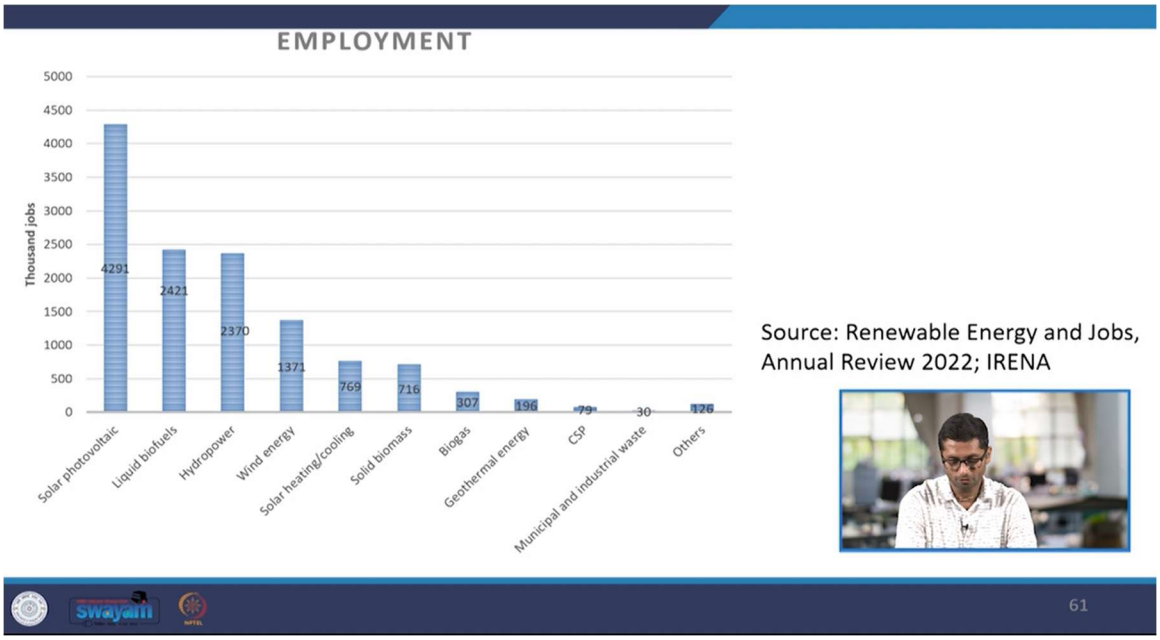


A lot of emphasis is now being paid by the different countries on the different energy storage options and a majority of countries are banking on the different kinds of batteries which could be lithium ion batteries, vanadium flow batteries. In India we are also concentrating on pumped storage which means you pump water at a particular height when the electricity is available cheaply and you then use this water in the form of a hydropower plant when the electricity is not available from a renewable energy source. Other sources of energy could be compressed air where you compress the air and store it with the help of cheap electricity and use this compressed air for the production of electricity when renewable electricity is not available. A further example or further option could be solar thermal where you have solar thermal energy that could be used for

raising temperature of molten salts and the energy is stored in the form of heat in this molten salts and this energy could be recovered in the absence of renewable energy.



Plus we also see that a lot of momentum is now given to the forecasting of the solar or wind or different flexible sources of energy because these end sources of energies are variable in nature and with the advent of artificial intelligence and machine learning the algorithms could be made so as to predict the production of energy in a fairly nice manner. Plus these kinds of algorithms are also applied towards the price forecasting how the electricity would be available in the near future.



Again if we see there is a good amount of employment opportunities that are coming in this sphere so this is the data that I got from the report by IRENA and International Labour Organization where they have predicted that good amount of jobs would be coming up in the renewable energy sector which could be the solar, the biofuels, hydropower, wind, solar and geothermal. So in the future we are going to see a good amount of intervention that are going to take place because of the advent of renewable and clean sources of energy. So with this we take a break for today's lecture. In today's lecture we have tried to understand that as we proceed in the future there is going to be an increase in the energy consumption and this energy consumption could come from different sources and all different sources of energy could have their advantages and disadvantages.

In today's class we have tried to understand what are the typical advantages and disadvantages with different renewable or clean sources of energy and with this we end today's lecture. Thank you.