Hydrogen Energy: Production, Storage, Transportation and Safety
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Lecture - 69
Utilisation in Different Sectors, Global Status and Future Directions

This is the last lecture of this course which is on Utilisation of hydrogen in Different Sectors. We will also see very briefly the global status and how the hydrogen economy, the future directions of hydrogen in the hydrogen energy value chain is going to evolve.

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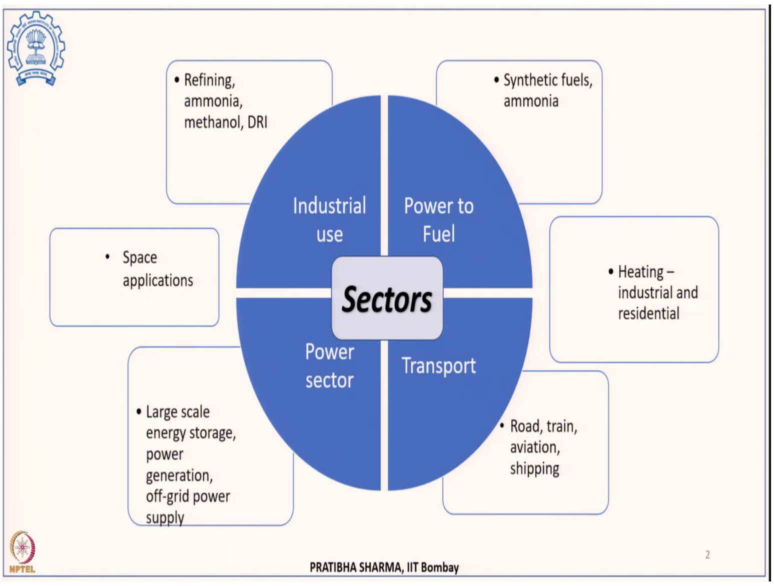

Now, the different sectors if we see in which hydrogen is either currently used or will have a future usage includes the major use of hydrogen is in industrial segment, wherein it is used as a feedstock for refining, ammonia synthesis, methanol synthesis and DRI process. The major application of hydrogen which has been for very long time was for space applications.

But, then the use of hydrogen will increase in other segments like as a fuel, synthetic fuel and there hydrogen will be converted from electrolytic hydrogen to fuel for producing different liquid fuels and for ammonia as well. Or, it will also find its application in transportation segment; either it is a road transport or a train transport, aviation or shipping. It will also find application in power sector, where it could be used for large scale energy storage for power generation or for off grid power supply.

At the same time certain amount of application of hydrogen will also come from heating sector, where an industrial heating, high temperature industrial heat is required or for the residential heating. Now, for a long time hydrogen we know that has been used in refineries. If we consider the demand of hydrogen in refineries, this is 33 percent of the total demand.

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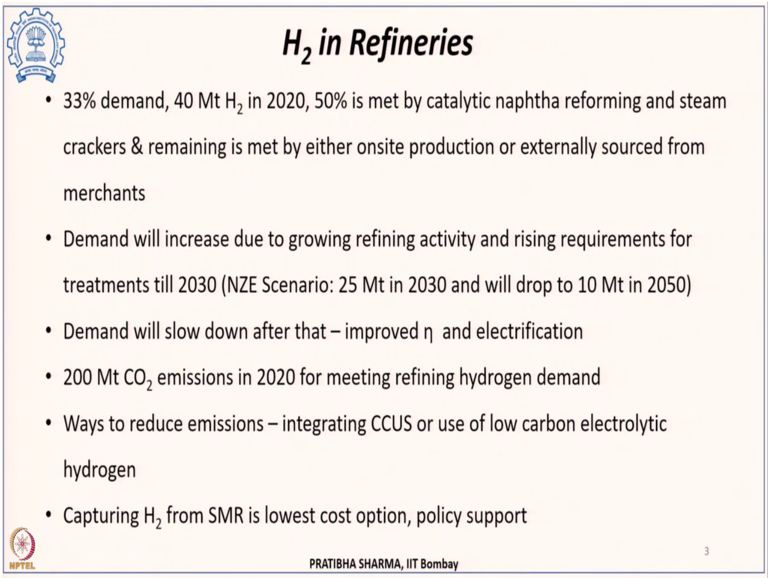

In 2020, this demand was 40 million metric tons and out of that 50 percent of that demand came from catalytic naphtha reforming or from steam crackers. And, rest of it was either it was produced by an onsite production plant or it was externally sourced from a merchant hydrogen plant.

Now, we know that the requirement of hydrogen in refineries is for various processes that we have also seen earlier, that it is used for various hydro treatment processes and for various hydro cracking processes.

This demand of hydrogen will increase due to the growing refining activity and also because of the rising requirements for the treatment. As the fuel norms, the emission norms get more and more stricter, this demand will increase is expected to increase till 2030 and thereafter there will be a decline in the demand. This is what is being expected.

Now, there are different scenarios, like the net zero emissions scenario, it predicts that the demand will decrease and it will become 25 million tons by 2030 and will drop to 10 million tons by 2050. So, there are different scenarios. There is a pledged scenarios, announced pledged scenario which has a different finding in the net zero emissions scenario that is more optimistic, that has a different findings. However, it is also expected that this demand in refineries will slow down after 2030.

There will be certain other factors other than the demand of oil and oil products. There will be an improvement in the efficiency, there will be increased electrification that will also contribute towards slowing down the demand after 2030. Now, this use of fossil fuels in the refinery that is contributing currently to 200 million tons of carbon dioxide emissions in 2020 for meeting the demand of the refinery which is hydrogen demand.

But, currently this most of the hydrogen demand it is met by the different fossil fuels. Now, to address this challenge of these carbon dioxide emissions and to reduce the emissions, the two possibilities are either to integrate carbon capture use and sequestration or use low carbon electrolytic hydrogen. Now, if we see these two aspects then capturing hydrogen from SMR plants is the lowest cost option and integration of CCUS with that also will require a policy support.

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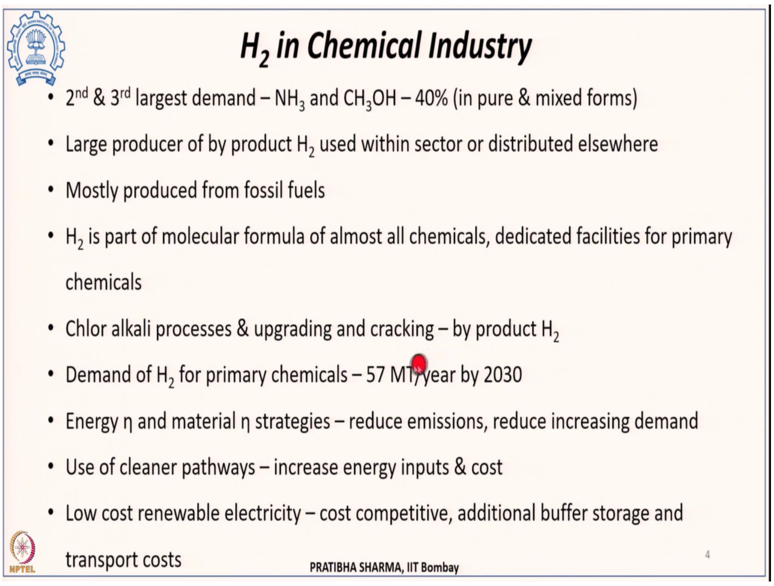

Now, the another major sector where which uses hydrogen currently which is an industry which currently is using about 40 percent of hydrogen in pure and mixed form or mixed gases form. And, this is the sector which is the 2nd and 3rd largest hydrogen consumer in terms of producing ammonia, fertilizers and for methanol production. So, the 2nd and 3rd largest demand comes from the chemical industry.

And, this particular sector is not only a major consumer of hydrogen, but it is also a major producer of hydrogen. But, whatever hydrogen which is being produced in a chemical industry that is used within the industry itself and some amount these are being distributed elsewhere. So, this most of the hydrogen which is used in the chemical industry, currently it is being produced from the fossil fuels.

Now, if we see whatever chemicals we see the major chemicals which are being produced whether it is ammonia or methanol or ethylene or propylene or whether it is the mixed xylenes; hydrogen is an important component, it is a part of their molecular formula for almost all chemicals. But, only for ammonia and methanol which are the primary fuels dedicated hydrogen production facilities are there in their industries.

Now, the two major industries wherein we can get by product hydrogen are the chlor alkali processes, chlor alkali industry and also wherein we are upgrading or cracking the high value chemicals. So, both these processes, the chlor alkali process and upgrading and cracking of the high value chemicals that gives by product hydrogen. Now, if we see the demand of hydrogen in the chemical industry, it will also grow and it will become 57 million tons per year by 2030.

This increasing demand will slightly slow down, if there is an increase in the energy efficiency and provided the material efficiency strategies are being followed. And, at the same time if there are norms associated with the reduction in the emissions. Now, this supply of hydrogen will be there required for producing definitely the primary chemicals and other chemicals.

But, the possibility to reduce these emissions could be use of cleaner paths. So, these use of cleaner paths could be low carbon, hydrogen could be used or carbon capture use and sequestration, but all these will add up to the energy input as well as cost. Now, if we low cost renewable electricity is used, in some of the countries which have a high renewable energy potential and their electricity price are currently also low, they are cost competitive.

So, the hydrogen produced for the chemical industry are currently also cost competitive as compared to the production of hydrogen from the natural gas or coal. But, the only additional requirement will be that, since these renewables based electricity will be, there will be intermittency associated with the renewables there will be an additional requirement of buffer storage.

And, then these renewal power plants may not be near close to the chemical industry. So, there will be a cost associated with the transport of hydrogen. Now the another major industry where hydrogen is being used is iron and steel industry.

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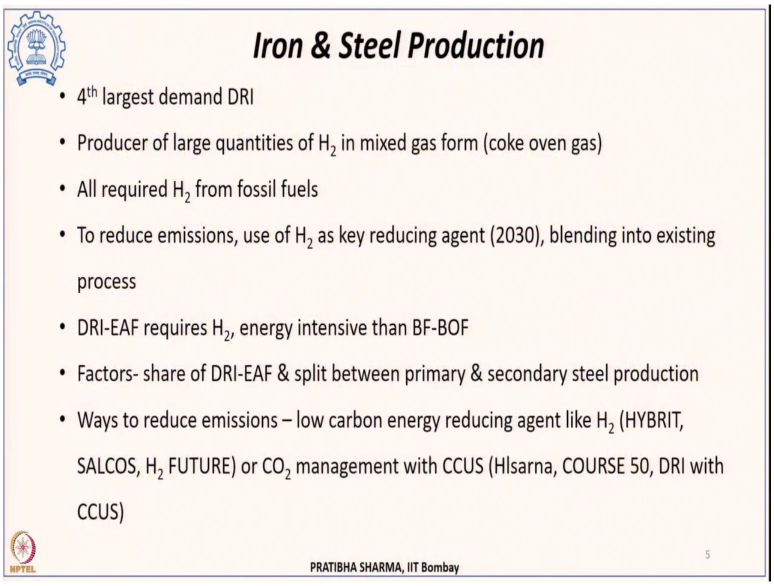

And, that is the 4th largest demand for the DRI: Direct Reduction of Iron for production of steel. It is also like the chemical industry another major producer of hydrogen, but that is in the mixed gas form, coke oven gas. And, whatever required hydrogen currently is being produced from fossil fuels.

So, that leads to a lot of emissions and if we want to reduce those emissions, because of the hydrogen production for its use in the iron and steel industry, the requirement is instead of using the other carbon based hydrogen; if we use pure hydrogen as the key reducing agent. And, then there are projects, commercial projects which will demonstrate that and these will be operational soon or the other possibility could be either use hydrogen as the key reducing agent or blend it with the existing processes to a certain extent.

Now, the two major processes which are used in iron and steel industry for the production of steel is the DRI-EAF that is the Direct Reduction of Iron Electric Arc Furnace and BF-BOF that is Blast Furnace Basic Oxygen Furnace. Now, the hydrogen requirement is in DRI-EAF and it is an energy intensive process compared to the conventional process which is BF-BOF.

And, what will be the share or the hydrogen demand in iron and steel industry will be basically determined by factors like what will be the share of electric arc furnace route against the basic oxygen furnace, blast furnace route. And, at the same time what will be the split between the primary and the secondary steel production. So, if we want to reduce the emissions with the associated with this hard to abate sector, the ways could be either use low carbon energy reducing agent which is hydrogen.

And, there are different demonstration plants like HYBRIT, SALCOS, hydrogen FUTURE, wherein hydrogen is projected as a reducing agent or the another possibility could be carbon dioxide management using CCUS and Hlsarna, COURSE 50, DRI with CCUS. These are the DRI with CCUS plants.

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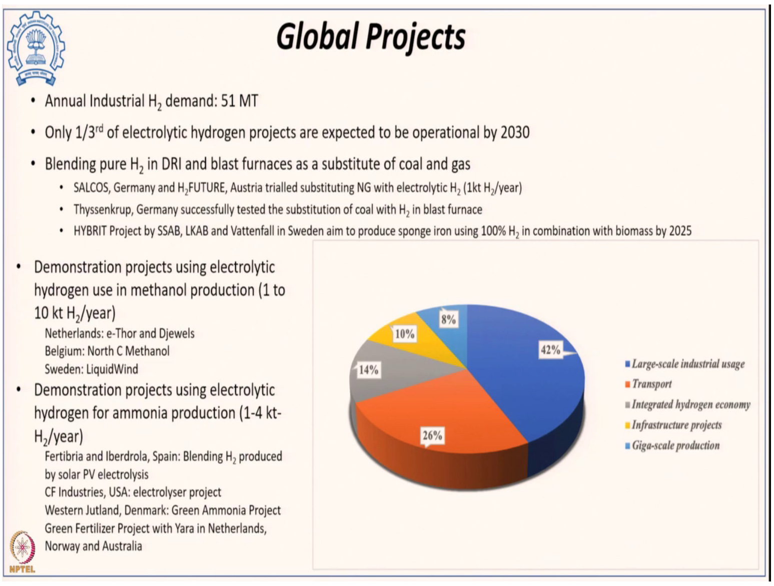

Now, if we quickly see the major global projects which are ongoing, let us say in the industrial segment the demand is 51 million tons; it is expected that by 2030 one-third of the electrolytic hydrogen projects will be operational. Now, if it comes to the iron and steel industry, blending of hydrogen in DRI and blast furnaces as a substitute to coal and gas. The different projects which are ongoing are SALCOS in Germany, hydrogen FUTURE in Austria.

And, there they are substituting natural gas with the electrolytic hydrogen. It is accounting for 1 kilotons of hydrogen usage per year. Thyssenkrup, Germany they have successfully tested the substitution of coal with hydrogen in blast furnace. The HYBRIT project in Sweden, it aims to produce the sponge iron using 100 percent hydrogen in combination with biomass by 2025.

Similarly, there are several demonstration projects using electrolytic hydrogen for methanol production like in Netherland, Belgium and Sweden. And, use of electrolytic hydrogen for ammonia production, these are ongoing in Spain, US, Denmark, Norway, Australia and Netherlands.

Now, if we quickly see such projects, similar such projects about 42 percent of these are for large scale industrial usage, 26 percent for transportation segment, about 10 percent are dedicated for the infrastructure projects, 8 percent for gigawatt scale production and 14 percent are for integrated hydrogen economy based projects.

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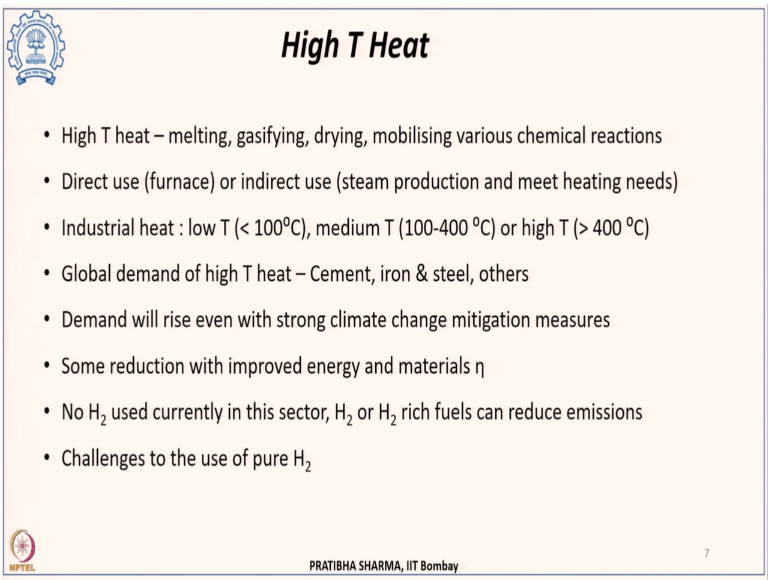

Another major segment where hydrogen can be used in future is providing the high temperature industrial heat. Now, when it comes to high temperature industrial heat, it is used in industries for different processes, different operations like melting, gasifying, drying, for several chemical reactions. And, either this heat is directly supplied in a furnace or it is given indirectly, like first steam is produced and then that is used to meet the heating demand.

Now, this requirement of heat that can be categorized into three categories, either a requirement of a low temperature heat, less than 100 degree centigrade or medium temperature 100 to 400 degree centigrade or high temperature greater than 400 degree centigrade. And, the major demand, global demand of this high temperature industrial heat comes from the cement industry, iron and steel industry and other industries. Now, the demand of this industrial heat will continue to increase even if there is a strong climate change mitigation measure that needs to be taken.

However, there will be some minor reductions which will be owed to the energy and material efficiencies. Currently, there is no hydrogen which is being used in this sector, but in future there will be demand of hydrogen or hydrogen rich fuels so, as to reduce the emissions which come along with the industrial heat supply. So, it could be either hydrogen, but the usage of pure hydrogen has several challenges. So, it will be hydrogen rich fuels which can reduce the emissions associated with the industrial heat production.

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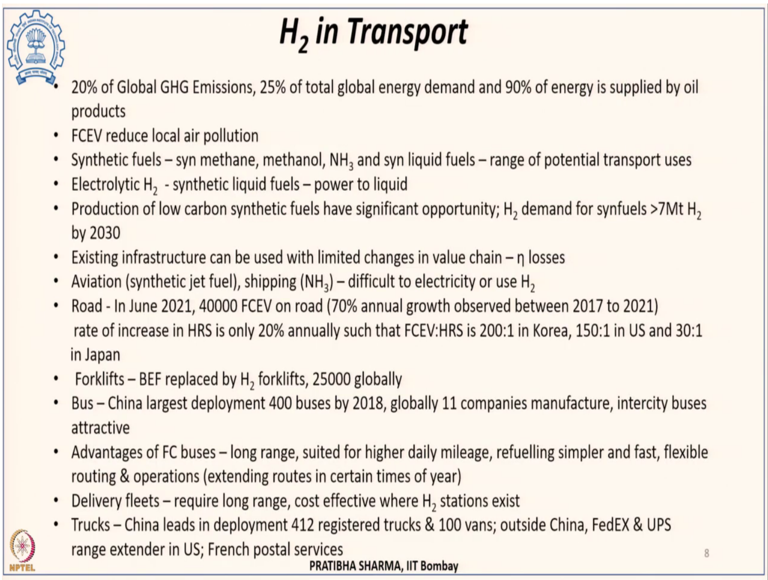

The major application that may find its way in future is hydrogen usage in transportation sector. Now, if we see the transportation sector, 20 percent of the global greenhouse gas emissions comes from the transportation sector. At the same time, it uses 25 percent of the total global energy, 90 percent of the energy which is used in the transportation sector comes from the oil products. If we are able to electrify it by either battery electric vehicles or fuel cell electric vehicles, the emissions related to the transportation sector could reduce.

Here in fuel cell electric vehicles can have the potential to reduce the local air pollution, as they have no tail pipe emission like the battery electric vehicle. It is also possible that we can have other than hydrogen other synthetic fuels like synthetic methane or methanol or ammonia or other synthetic liquid fuels which can find their application in wide range of transportation applications.

Now, if the hydrogen is being produced through electrolytic route and then that hydrogen is used to produce synthetic liquid fuels, it is known as power to liquid. Now, the production of these synthetic fuels, it is expected to increase and this demand of hydrogen for synthetic fuel production will grow to 7 million tons or higher by 2030. This use of synthetic fuels has several advantages, because we can use the existing infrastructure and as such we will have to make very limited changes in the energy chain.

However, the efficiency losses will be involved because we are converting it into different fuels, first to hydrogen and then into synthetic fuel. For aviation sector synthetic jet fuel will be will have a potential, for shipping segment ammonia could be used. But, then these are the sectors aviation and shipping where it is very difficult to either directly electrify or use hydrogen. So, there these synthetic fuels or hydrogen rich fuels will have a potential in future.

Now, when it comes to the road transport, in June 2021 there were about 40000 fuel cell electric vehicles on road. And, the positive point was that 70 percent of the annual growth was observed between 2017 and 2021. But, the rate of increase in hydrogen refuelling station was not to that scale, it was only 20 percent annual increase which was observed in this period. There are different forklifts, about 25000 forklifts globally operating and this is one of the important use of fuel cell based operations.

Among the bus transport, China has the largest deployment of 400 buses that was 2018. And, then there are globally 11 companies which manufacture fuel cell buses. And, it could find its way for intercity buses; it would be attractive for intercity transport. The advantage of fuel cell buses is they can provide longer range, a shorter refuelling time, at the same time the refuelling is simpler and faster with the fuel cell with hydrogen based transport.

And, it can provide a flexible as routing as well as it can provide flexibility in the operations. Like at times when in types in the year, if there is a change in the route or an extended route then fuel cell based bus can allow that flexibility. Delivery fleets which require long range operations which require long range of transport, it has been found by the operators and manufacturers that it is cost effective if there are hydrogen stations on the way.

Among trucks, China is the leading country having 412 registered fuel cell trucks and 100 vans. Outside China, FedEX, UPS they are coming up with their range extended in US and then the French postal service, they are also acquiring the hydrogen fuel cell trucks.

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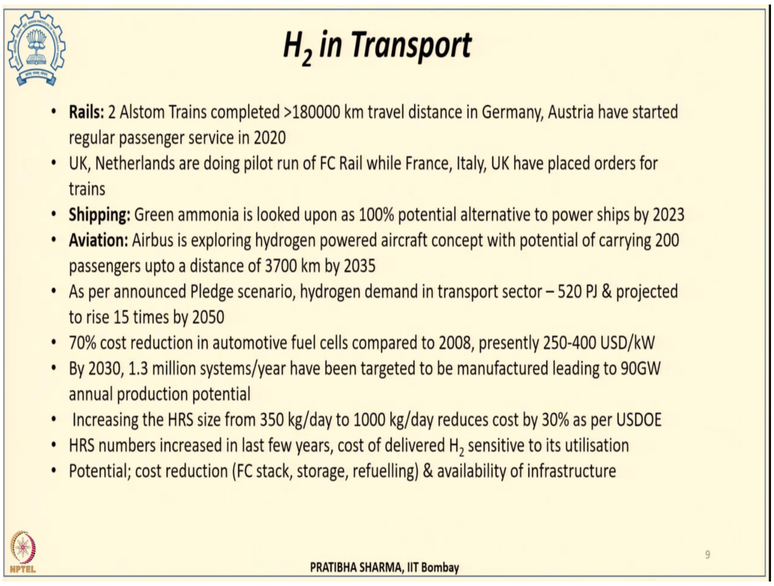

Among rail, we know the well-known Alstom train, there are now 2 such trains in Germany which have travelled more than 180000 kilometers of distance. Austria, they are also coming up with a regular passenger service in 2020. UK, Netherland they are coming up with a pilot fuel cell rail. France, Italy, UK they have placed orders for trains.

Among shipping sector, Green Ammonia is looked as a potential alternative to power the ships by 2023. For aviation, Airbus is exploring hydrogen powered aircraft concept and that will be used by 2035. As per the announced pledge scenario, the hydrogen demand in this particular segment which is the transportation sector will be of 520 petajoules and it is expected to rise to 15 times by 2050.

Now, the positive note is the cost of automotive fuel cell has reduced by 70 percent compared to 2008. And, then by 2030 it is expected that there will be 1.3 million systems per year to be manufactured leading to 90 gigawatt of annual production potential. Now, all these changes will require that there should be a cost reduction in terms of fuel cell stack costs, hydrogen storage cost, refuelling cost. And, then there should be an availability of the infrastructure, availability of hydrogen refuelling stations.

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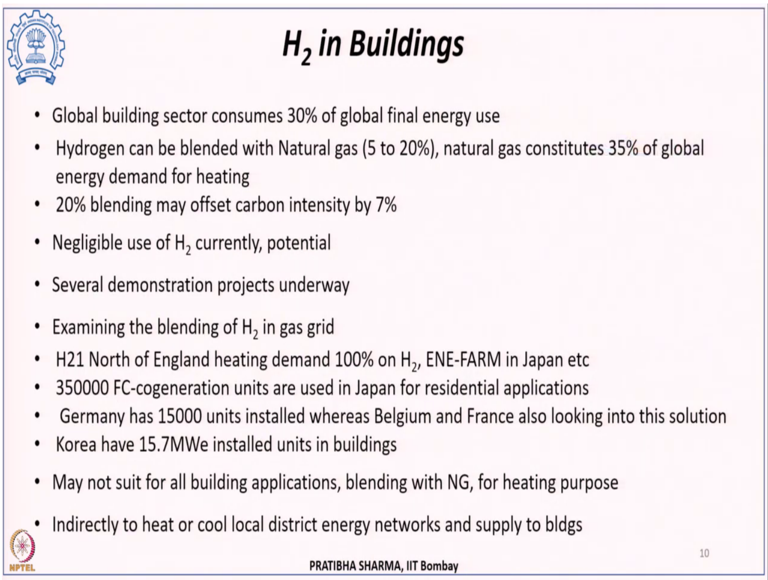

When it comes to use of hydrogen in buildings, building sector it consumes 30 percent of the global final energy. As such hydrogen is not being used in buildings currently, but it has a potential. And, that potential is if hydrogen is blended with natural gas, in that case it can be used for various operations. Although, blending of hydrogen with natural gas or pure hydrogen may not suffice all the building operations.

But, the blending with natural gas could be used for heating purpose in countries where lot of heating load requires natural gas. There has been several demonstration projects ongoing like the H21 North of England, they are they are planning for heating demand which could be met 100 percent by hydrogen. ENE-FARM in Japan and then in Japan, there are about 350000 fuel cell cogeneration plants which are meant for residential applications. Germany about 15000 units installed, in Belgium and France they are also looking into such solutions.

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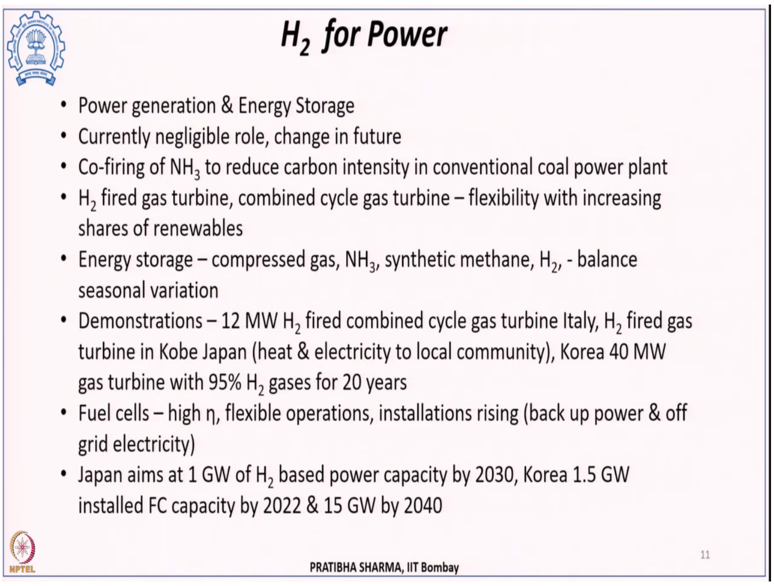

Another major segment where hydrogen will find its way is the power, both for power generation as well as energy storage. Currently, it is having negligible role in this particular sector, but it is predicted that there will be a change in the future. Now, for power generation, the possibilities are cofiring of ammonia to reduce the carbon intensity in the conventional coal power plant as well as hydrogen fired gas turbines, combined cycle gas turbines and that will provide flexibility with the increasing share of renewables.

For energy storage either compressed gas hydrogen can be used or ammonia can be used or it can be converted into synthetic fuels and that will help in balancing the seasonal variation or taking care of the intermittency of the renewables. There have been several demonstration going on across the world. A 12 megawatt of hydrogen fired combined cycle gas turbine demonstrated in Italy, hydrogen fired gas turbine in Japan which is providing both heat and electricity load to the local community.

Korea, they have been using 40 megawatt of gas turbine with 95 percentage of hydrogen for past 20 years. And Japan, it aims at 1 gigawatt of hydrogen based power capacity by 2030, Korea 1.5 gigawatt of installed fuel cell capacity by 2022 and 15 gigawatt by 2040.

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National Hydrogen Strategies

Country	Strategy Document & Year	Deployments Targets (2030)	H_2 Production method	Major End Use	Announced Public Funding
Japan	Strategic Roadmap for Hydrogen and Fuel Cells, 2019 Green Growth Strategy, 2020, 2021 (revised)	Total use: 3 Mt H_2/year Supply: 420 kT low-C H_2/year 8 lakhs FCEVs 1200 FC buses 10000 FC Forklifts 900 HRSs Demand: 3Mt NH_3 Fuel demand	Electrolysis Fossil Fuels with CCUS	Buildings Electricity Steel Industry Refining Shipping Transport	6.5 billion USD (2030)
Korea	Hydrogen Economy Roadmap (2019)	Total use: 1.94 Mt H_2/year 2.9 million FC cars (plus 3.3 million exported) 1 200 HRSs 80 000 FC taxis, 40 000 FC buses,30 000 FC trucks 8 GW stationary FCs (plus 7 GW Exported) 2.1 GW of micro-cogeneration FCs	By-product H_2 Electrolysis Natural gas with CCUS	Building Electricity Transport	2.2 billion USD (2020)
European Union	EU Hydrogen Strategy 2020	40 GW Electrolysis	Transition of NG with CCUS Renewable energy based Electrolysis	Industry Refining Transport	4.3 billion USD (2030)
Germany	National Hydrogen Strategy 2020	5GW Electrolysis	Renewable energy based electrolysis	Industry Refining Electricity Aviation Shipping Transport	10.3 billion USD (2030)

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Now, Japan was the first country which came up with the national strategy and that too was in 2017. So, that was the first country which came up with the national strategy. Now, today if we see there are about 30 countries which have come up with their strategy documents, road maps, mission documents; mentioning like how they are going to deploy the different hydrogen based technologies.

Some of the representative examples are like Japan, it came up with its strategic document on hydrogen and fuel cell in 2019. Another revision was in 2020 and 2021, that was green growth strategy and the targets for deployment are that they will be using 3 million tons of hydrogen per year. Along with low carbon hydrogen which will be 420 kilo tons of its use per year.

Japan has targeted 8 lakh fuel cell electric vehicles, 1200 fuel cell buses, 10000 fuel cell based forklifts and 900 hydrogen refuelling station by 2030. The method of hydrogen production that will be used for these for the meeting the hydrogen demand will be electrolysis and fossil fuels with CCUS. The major use of the hydrogen based technologies will be for buildings, for electricity, for steel industry, refineries, shipping and transport. And, a fund that has been announced is 6.5 billion US dollars by 2030.

The second major leading country is Korea. They have come up with their hydrogen economy roadmap and they have planned to use 1.94 million tons of hydrogen per year by 2030. With a plan to launch 2.9 million fuel cell cars, 1200 hydrogen refuelling station, 80000 fuel cell taxis, 40000 buses, 30000 trucks and then other applications like for stationary applications and for cogenerations.

The major of that hydrogen production will be as a by-product hydrogen, electrolysis, natural gas integrated with CCUS. And, the applications they are targeting are building, electricity and transport with a funding dedicated funding of 2.2 billion US dollars.

European Union came up with European Union Hydrogen Strategy 2020 And, the major deployment target is 40 gigawatt of electrolysis electrolyzers which is which will meet the requirement of industrial refineries and transport with a funding of 4.3 billion US dollars. Similarly, several other countries they have come up with their strategies like Germany with target of having 5 gigawatt of electrolysis installed by 2030.

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Country	Strategy Documents & Year	Deployments Targets (2030)	H_2 Production method	Targeted End Use	Announced Public Funding
Canada	Hydrogen Strategy For Canada 2019	Total use: 4 Mt H_2/year 6.2% of total final energy consumption	Biomass By-product H_2 Electrolysis Natural gas with CCUS Oil with CCUS	Building Electricity Industry Mining Refinery Shipping Transport H_2 Export	19 million USD (2026)
France	Hydrogen Deployment Plan, 2018 National Strategy for Decarbonized Hydrogen Development, 2020	6.5 GW electrolysis 20-40% industrial H_2 decarbonised 20 000-50 000 FC Light Duty Vehicles 800-2000 FC Heavy Duty Vehicles 400-1000 HRSs	Electrolysis	Industry Refinery Transport	8.2 billion USD (2030)
Netherlands	National Climate Agreement, 2019 Government Strategy on Hydrogen, 2020	3-4 GW electrolysis 300 000 FC cars 3000 FC Heavy Duty Vehicles	Renewable Energy based Electrolysis Natural Gas with CCUS	Building Electricity Industry Refinery Shipping Transport Aviation	80 million USD/year
United Kingdom	UK Hydrogen Strategy 2021	5GW low carbon-H_2 production capacity	Natural Gas with CCUS Electrolysis	Building Electricity Industry Refinery Shipping Transport Aviation	1.3 billion USD

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Canada, they have a hydrogen strategy which was the document which was released in 2019, targeting 4 million tons of hydrogen usage per year and a funding of 19 million dollars. Similarly France, Netherland, United Kingdom, Norway, Russia, Spain, Portugal and Czech Republic; they have come up with their hydrogen strategies.

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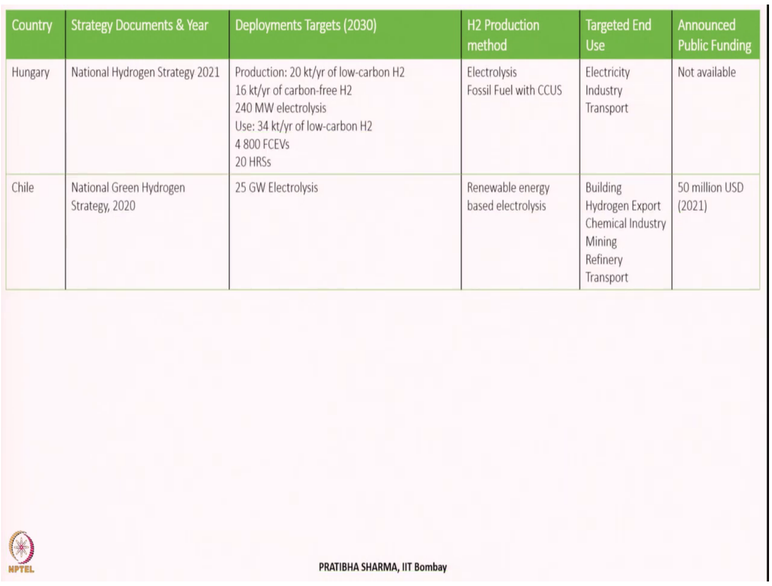

Country	Strategy Documents & Year	Deployments Targets (2030)	H2 Production method	Targeted End Use	Announced Public Funding
Hungary	National Hydrogen Strategy 2021	Production: 20 kt/yr of low-carbon H2 16 kt/yr of carbon-free H2 240 MW electrolysis Use: 34 kt/yr of low-carbon H2 4 800 FCEVs 20 HRSs	Electrolysis Fossil Fuel with CCUS	Electricity Industry Transport	Not available
Chile	National Green Hydrogen Strategy, 2020	25 GW Electrolysis	Renewable energy based electrolysis	Building Hydrogen Export Chemical Industry Mining Refinery Transport	50 million USD (2021)

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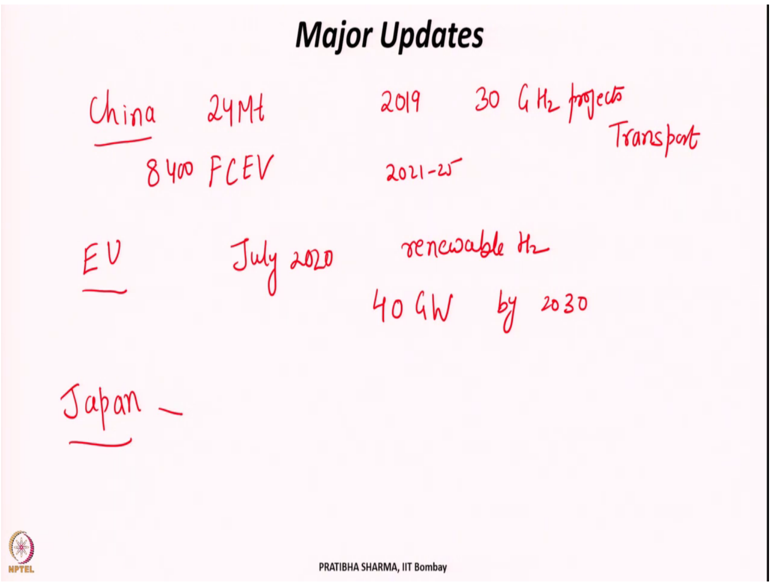

Just to give some major global updates, China has been leading, China if we see they have 24 million tons of hydrogen consumption per year. And, this is the world's largest user as well as producer of hydrogen. If we see by since, 2019 if we see then China had more than 30 green hydrogen projects in operation. They came up with their first hydrogen roadmap in 2016 and they basically focused on transport.

So, there are some 10 countries who have not come up with the strategies, but they are leading. They have 8400 fuel cell electric vehicles and they are the 3rd largest FCEV fleet in operation after Korea and US. Although, they do not have a strategy, but they came up with their plans, 5 year plans 2021 to 25 with the major focus is that hydrogen will be a leading industry out of the 6 industries.

European Union they have come up with their strategy in July 2020 and they have mentioned that hydrogen will be given a key priority and the focus will be on renewable hydrogen. The major target is to install 40 gigawatt of renewable hydrogen electrolyzers by 2030 which is the huge number and they aspire to become industrial leader in the clean hydrogen. Japan was the 1st country to come up with the national hydrogen strategy and that was in 2017.

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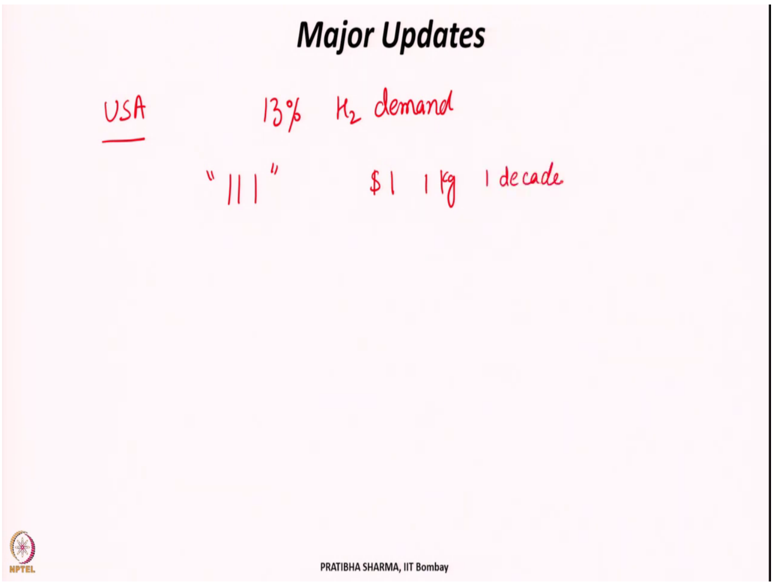

USA which is the 2nd largest consumer and producer of hydrogen that accounts for about 13 percent of the global hydrogen demand. Although, they have not come up with the hydrogen strategy roadmap or mission document, but they have been leading, they are the world's largest fuel cell electric vehicle market. They have come up with 111 goal which means that the cost of clean hydrogen will be 1 dollar per kg in 1 decade.

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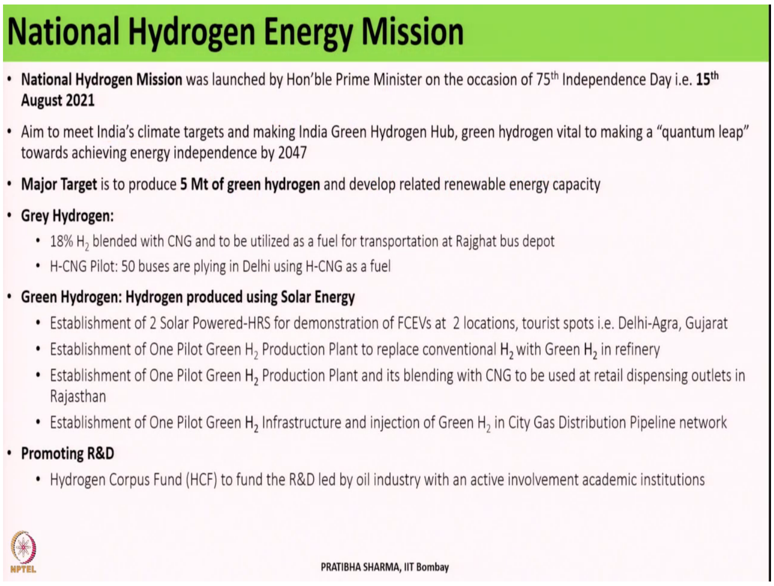

Now, if we look at the India country status, the National Hydrogen Energy mission which was launched by our Honourable Prime Minister on 15th of August, that aims at meeting India's climate change target and making India Green Hydrogen Hub. And, this is towards taking a quantum leap towards the achieving energy independence by 2047. So, the major target in the national hydrogen energy mission of India is to produce 5 million tons of green hydrogen through renewables.

And, 18 percentage of grey hydrogen will be blended with CNG and that will be utilized as a fuel for transportation. About 50 buses will be plying at the 2 tourist spots, it will be used in Delhi and that will be using H-CNG fuel. There will be 2 solar powered hydrogen refuelling stations that will be at the 2 tourist spots of between Delhi and Agra and at Gujarat. One pilot green hydrogen production plant to replace conventional hydrogen with green hydrogen in refinery.

Another one where in one green hydrogen plant will replace and its blending will be done with CNG at a retail dispensing outlet. Similarly, there are other such pilot projects which are planned.

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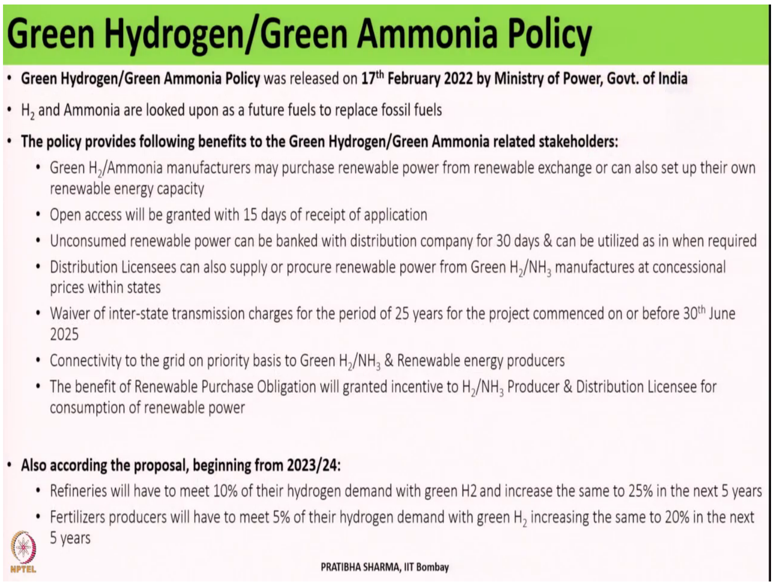

In February 2022 by Ministry of Power, Government of India, Green Hydrogen and Green Ammonia Policy was launched, this was released. And, here the target is hydrogen and ammonia are looked upon as a future fuel to replace fossil fuels. There have been several incentives, benefits which have been provided to the related stakeholders.

And, also there has been certain proposals like the refineries will be meeting their 10 percent of the hydrogen demand by means of green hydrogen and this will be increased to 25 percent in the next 5 years. Similarly, fertilizer industries they will meet the 5 percent of their hydrogen demand by means of green hydrogen which will be further increased to 20 percent in the next 5 years.

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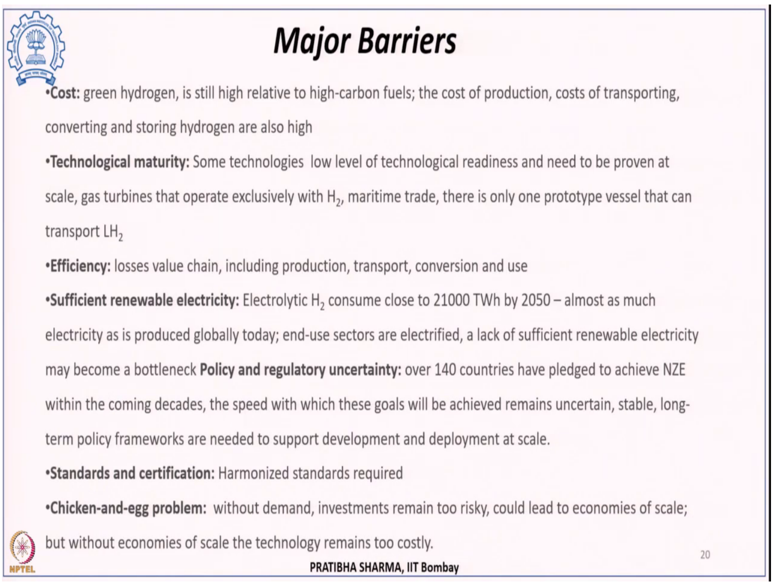

Now, if we look at the major barriers that we can see towards widespread deployment of hydrogen based technologies, the first major barrier is the cost of green hydrogen which is high compared to the high carbon fuels. And, as such the cost involved in both in all the aspects of the hydrogen value chain whether it is transport, storage or utilization that is relatively high. However, the economies of scale and learning curve will reduce that cost.

At the same time, some of the technologies like power generation with gas turbines using hydrogen that are not at the required TRL levels and that will take some time. Since, the process involves several steps, there are losses involved in the entire value chain whether it is production, transport, conversion or usage. So, the efficiency becomes relatively lower. At the same time, if the entire hydrogen demand is to be met by electrolytic hydrogen, in that case the requirement of electricity will be very high.

And, when electrification together will be going on along with the use of electrolytic hydrogen, there may be a lack of sufficient renewable based electricity that may become the major bottleneck. At the same time there is a requirement of having harmonized standards policies so, that the standards, regulations and regulatory certainty should be there.

So, that the international trade could increase, at the same time that will speed up the goals of the different either net zero energy scenario or the announced pledges scenario.

And finally, the chicken and egg problem wherein the demand without demand the investment becomes risky and that will come the with the cost will come down with economies of scale and without economies of scale the technology remains too costly. So, that remains as a chicken and egg problem.

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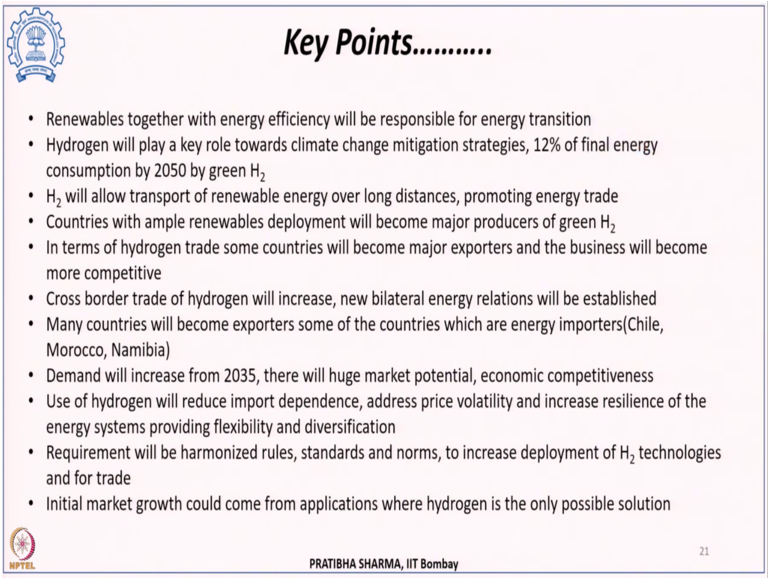

So, the key points that we have seen from the entire global and Indian scenario is that renewables together with the energy efficiency will be responsible for the new energy transition, where in hydrogen is going to play a key role and it will play a role towards climate change mitigation strategies. It is expected that 20 percent of the final energy consumption will come from green hydrogen by 2050.

It will be used for transportation sector specifically for long distance transport and usage of hydrogen will promote energy trade. There are certain countries wherein there is enough of renewables deployment, the renewable power pricing is less and that will become the major producers of green hydrogen. When it comes to hydrogen trade, there will be countries which will become major exporters and that business will become more and more competitive.

So, there will be a cross border trade of hydrogen so, the geopolitical relationships will change. So, the countries which have not done energy trading will now come into bilateral energy relationships. Some of the countries which have been major importers of energy, they will become exporters because of their renewable power generation. Energy demand will increase by 2035 and then there will be a huge market potential and economic competitiveness with the use of hydrogen based technologies.

And, we have already seen in this course throughout that hydrogen use in the energy sector will reduce import dependence, will address the price volatility, will increase the resilience of the energy systems and will provide the flexibility and diversification.

So, as such there is a need for harmonizing rules, standards and norms and increasing the deployment of hydrogen based technologies for future trade. So, it is expected that initial market growth will come from those applications where hydrogen is the only solution or is one of the possible solutions.

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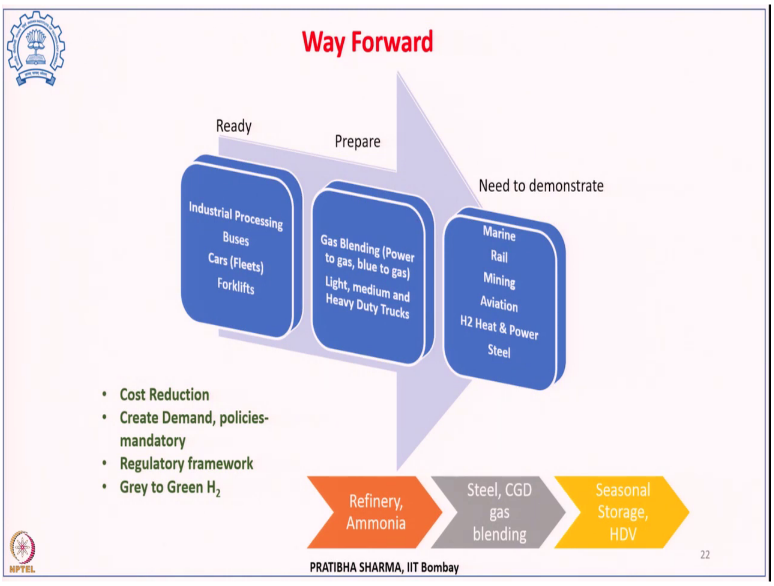

So, if we see there are certain segments where we can readily use in the current scenario. Like the various industrial processes, for transportation segment for heavy duty transport. There are certain sectors where we need some preparedness before it will come into widespread use like blending and light and medium duty vehicles. And, there are certain segments where it has to be demonstrated further before it could be used like marine, rail, mining, aviation, heat and power and steel.

The major driving factors will be cost reduction, creation of demand. There will be requirement of policy mandates, carbon pricing, added there would be requirements of policies which mandates the use of green hydrogen. Regulatory framework is required and then there will be conversion from grey to green hydrogen.

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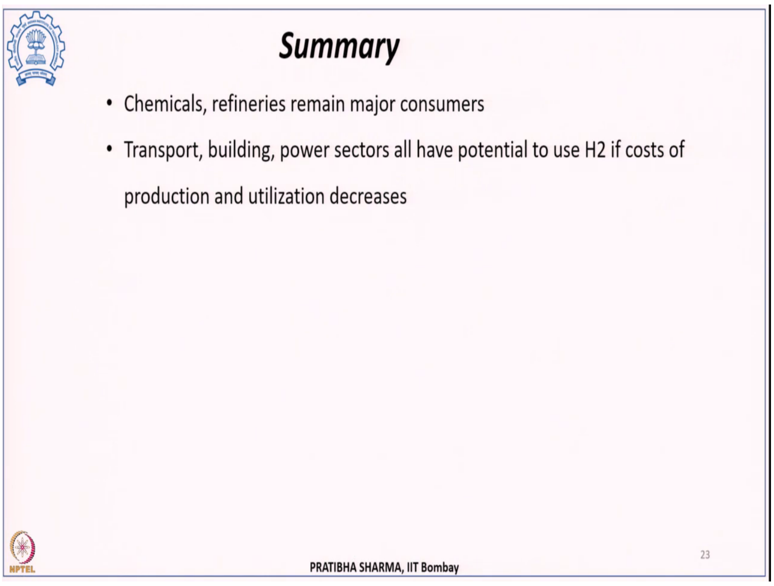

To summarize, what we have seen? We have seen the different sectors which are currently using hydrogen, sectors which will be using hydrogen in future wherein chemical refineries they remain the major consumers. And, these are the conventional sectors which have been using hydrogen for decades.

However, there are certain segments which will come up with hydrogen demand like transportation sector, building and power sectors and there the requirement will be to reduce the cost of production and utilization.

Thank you.