

Electrochemical Energy Storage
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Module - 11
Li resources and recycling of Li ion batteries
Lecture - 52
Nature and Geological Origin of All Potential Lithium Resources

Welcome to my course Electrochemical Energy Storage and this is module number 11 which is Lithium resources and recycling of lithium ion batteries and we are now in lecture number 52, where I will be describing the Nature and Geological Origin of All Potential Lithium Resources. This topic already I introduced in the last lecture, lecture number 51 and we are continuing that.

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CONCEPTS COVERED

- Lithium resources
- Li resources – Resources, reserve base, reserves
- Market share of precursors
- Li reserve – do we have enough?
- Global distribution of other battery material
- Li cost fraction of the cell and battery cost: An estimate

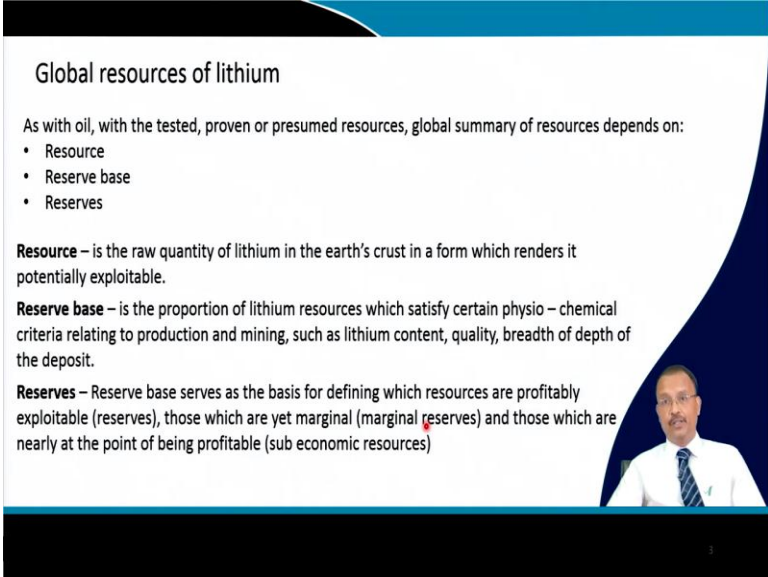
Lithium carbonate and lithium foil

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Now, lithium resources you know that what exactly are the product; lithium carbonate is the major one, lithium hydroxide is the second major precursor. Apart from that, lithium metal foil is also used in certain futuristic battery and all research purpose use; for the half cell characteristics, we do use lithium foil. So, the lithium resources, what are the reserve base and how much reserves are there, will be talking about; market share of the precursor again, we will describe it.

Lithium reserve, the question also remains that whether we have enough lithium. And the global distribution of other battery materials, there are certain precious material that is being used in lithium ion battery that transition metal like nickel and cobalt, they are expensive expensive. So, we will have a look and lithium cost fraction of the cell and battery cost, some estimate we will do.

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Global resources of lithium


As with oil, with the tested, proven or presumed resources, global summary of resources depends on:

- Resource
- Reserve base
- Reserves

Resource – is the raw quantity of lithium in the earth’s crust in a form which renders it potentially exploitable.

Reserve base – is the proportion of lithium resources which satisfy certain physio – chemical criteria relating to production and mining, such as lithium content, quality, breadth of depth of the deposit.

Reserves – Reserve base serves as the basis for defining which resources are profitably exploitable (reserves), those which are yet marginal (marginal reserves) and those which are nearly at the point of being profitable (sub economic resources)



So, with oil that tested and proven or presumed resources as has been done for the oil industries. The global summary of resources, they depends mainly on the resources and the reserve base and the reserve. So, what are those terms? Resources that is the row quantity of lithium in earth’s crust in the form which renders it potentially exploitable. So, how much is available in the earth crust? The upper part of the globe.

Reserve base, this is the proportion of lithium resource which satisfy certain physio chemical criteria that relates to their production and mining that is lithium content, quality of the lithium, breadth and depth of the deposit; whether it is profitable for you to extract the lithium.

There may be lithium in this reserve base, but this guidelines must have to be satisfied whether you have enough lithium, once you try to extract it along with other by products; whether you get sufficient quantity of lithium; whether it is cost effective, your mining installation cost, the carriage cost and also, the people who will be walking there, you

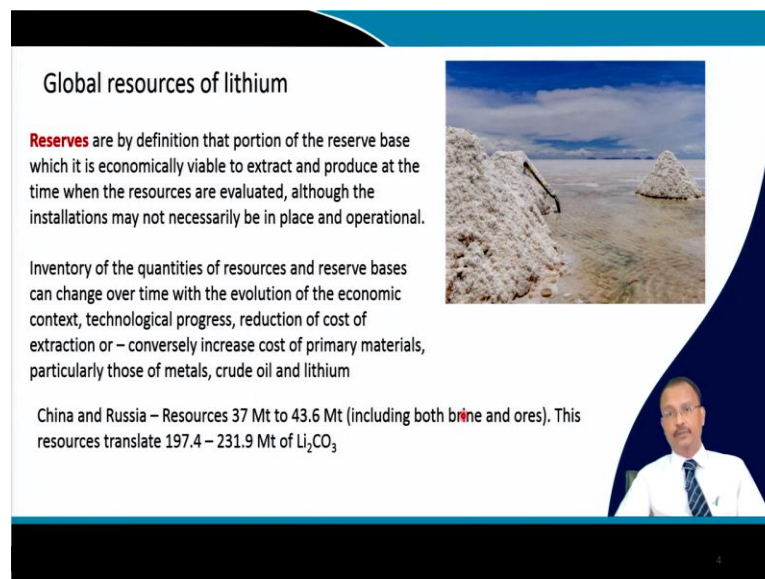
will have to make a colony. So, all this cost will be included here. So, that is the reserve base.

And reserves, reserve base they as I said serve as a basis for defining which resources are profitable or exploitable. So, that the profitable resources that is the reserve. The profitable resources of the reserve base that is basically the reserve, where what we should exploit.

And this, while you decide this, you will have to decide that which reserve base, they are marginal reserve. You just cannot make the cost of extracting the lithium, but still it is profitable and which are nearly at a point of being profitable.

So, which one are profitable and which one are nearly profitable based on the current price because price will go up and down. As you depleted with the lithium, then you will see that it is a precious material like gold or platinum kind of thing. So, little bit lithium, if it is available, your cost increases; [FL] that means, you can convert those reserve base to reserve.

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Global resources of lithium

Reserves are by definition that portion of the reserve base which it is economically viable to extract and produce at the time when the resources are evaluated, although the installations may not necessarily be in place and operational.

Inventory of the quantities of resources and reserve bases can change over time with the evolution of the economic context, technological progress, reduction of cost of extraction or – conversely increase cost of primary materials, particularly those of metals, crude oil and lithium

China and Russia – Resources 37 Mt to 43.6 Mt (including both brine and ores). This resources translate 197.4 – 231.9 Mt of Li_2CO_3



So, reserve by definition is that portion of the reserve base which is economically viable to extract and produce at the time, when the resources are evaluated. So, that is very important. So, today, it may not be profitable you think that part of the reserve base; but tomorrow, it may be your reserve. So, the installation may not necessarily be in place

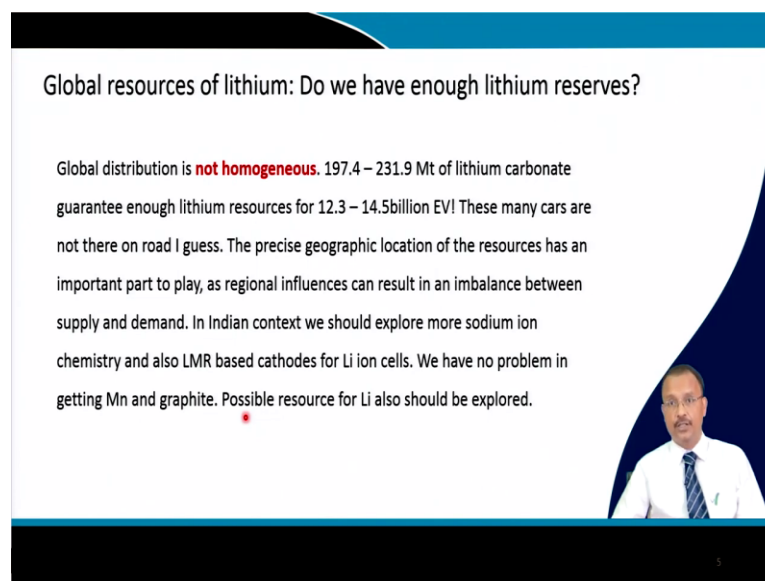
and operational. So, in this reserve base may be you think that today it is not a profitable; so, but tomorrow it may be profitable.

So, inventory of the quantities of the resources and reserve basis that can exchange over time with the evaluation of economic context. Exactly what I was talking about few minutes back. So, today it may not be profitable, tomorrow it may be profitable. Technological progress is another aspect. You may have devised a very easier way to extract it. So, today, it is expensive, tomorrow it may not be that much expensive.

Reduction of cost of extraction that is important and conversely, increased cost of the primary material; particularly, those of metal, crude oil and lithium. So, if the price rises, then maybe that will be very profitable. But if you can invent other resources, other reserve basis that basically have easier extraction feasibility, then it may be quite expensive on the contrary. So, China and Russia in the last lecture, we have seen resources are about 37 million tons to 43.6 million tons that includes both the ores for extraction and brine from the lake water.


So, if you translate this ore, you can roughly get about 197.4 to 232 million tons of lithium carbon. So, that is just to give you a rough resource; I mean rough estimate about the translation from the ore to the usable precursor material to make the lithium ion batteries.

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Global resources of lithium: Do we have enough lithium reserves?

Global distribution is **not homogeneous**. 197.4 – 231.9 Mt of lithium carbonate guarantee enough lithium resources for 12.3 – 14.5 billion EV! These many cars are not there on road I guess. The precise geographic location of the resources has an important part to play, as regional influences can result in an imbalance between supply and demand. In Indian context we should explore more sodium ion chemistry and also LMR based cathodes for Li ion cells. We have no problem in getting Mn and graphite. Possible resource for Li also should be explored.

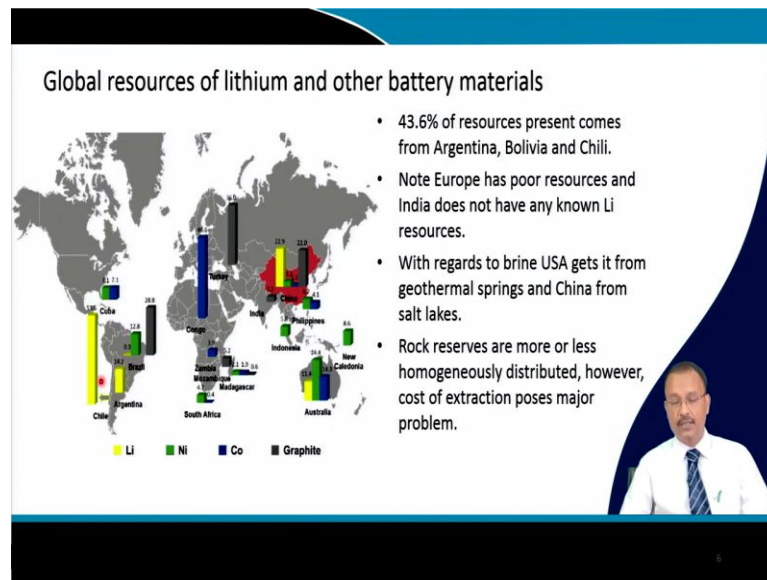


So, global distribution as you have say seen in my earlier lecture slide that is not homogeneous. So, this 1978 to 232 million tons of lithium carbonate, they guarantee enough lithium resources. Roughly, they will translate about 12.3 to 14.5 billions of sedan type of electric vehicles. So, I guess this many cars are not there now. So, you have enough lithium resources according to my calculations from the existing data whatever I could collect. But the geographic location of the resource that has an important part to play that I want to stress.

Regional influence is one, today China can say that all the lithium whatever we are having, we will make our own cell, we will not export any kind of raw material. So, that can imbalance that can have create an imbalance of supply and demand. And this also I told earlier that Indian context, since we do not have lithium resource, we should explore more sodium ion chemistry and also LMR base cathode material for lithium ion cells because in LMR base cathode material although more lithium will be required, but manganese is the major material that we use and nickel and cobalt content is grossly reduced.

So, manganese and graphite, we have plenty. We should therefore focus on this and other types of resources also should be explored because who knows maybe we also will have the possibility to get more lithium in your future in our country. But we should explore the possibility to recycle the lithium that is one and second one is to use more LMR base high voltage, high capacity cathode and sodium ion will have plenty of them, plenty of sodium ion battery resources. So, why not to explore sodium ion battery instead of lithium ion battery for our indigenous purpose.

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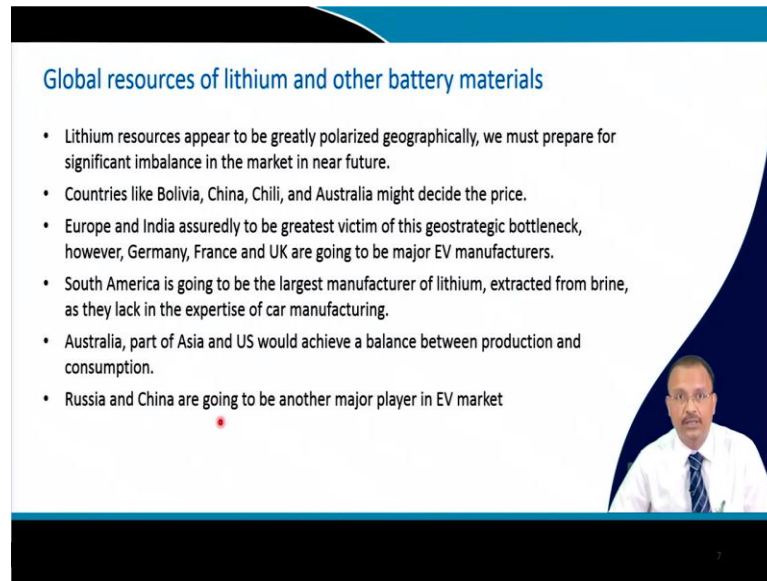


So, this is the global resource of lithium and other battery material. The curve one should see little bit, we should be patient in looking at this curve because the small lettering. 43.6 percent of resources is coming from countries like Argentina, the yellow marked one is lithium; the green marked one is nickel; cobalt is blue one and graphite is the blackish one. So, we do have graphite resources in India. We have manganese plenty. But as you can see nickel, cobalt, lithium, we do not have. So, Europe has poor resources and India does not have any known lithium resources.

So, the good automobile industries, they are located in Europe; particularly in Germany, but they not have any lithium and we also do not have any lithium. With respect to the brine from salt lake brine USA gets it from geothermal springs and China from salt lakes.

So, they have plenty of lithium extracted from the brines and other source as I told from minerals, so that rock reserves are more or less homogeneously distributed; cost of extraction that is more in case of mining. US is having it both the resources, China also is having both the resources and Southern part of America, they have mostly brine. So, this is the global resource distribution as per lithium as well as other precursor constituents are concerned.

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Global resources of lithium and other battery materials

- Lithium resources appear to be greatly polarized geographically, we must prepare for significant imbalance in the market in near future.
- Countries like Bolivia, China, Chili, and Australia might decide the price.
- Europe and India assuredly to be greatest victim of this geostrategic bottleneck, however, Germany, France and UK are going to be major EV manufacturers.
- South America is going to be the largest manufacturer of lithium, extracted from brine, as they lack in the expertise of car manufacturing.
- Australia, part of Asia and US would achieve a balance between production and consumption.
- Russia and China are going to be another major player in EV market

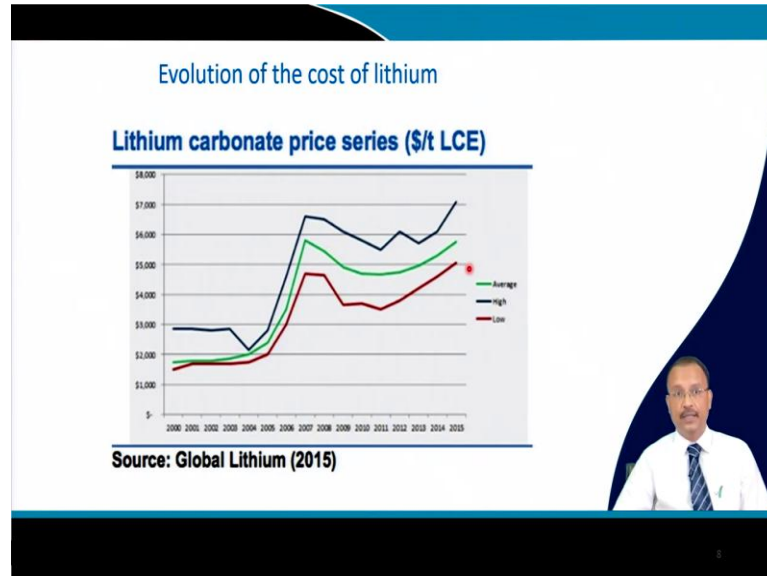
So, lithium resources appeared to be greatly polarized geographically. So, we must prepare for significant imbalance in the market in near future, who is having the precursor, they should control, they will control the price. Countries like Bolivia, China, Chili and Australia must decide the price because they have the resources. Europe and India assuredly be greatest victim of this geostrategic bottleneck; we have no control on it. But Germany, France and UK are going to be the major EV manufacturers. So, that is one problem; they will have to get the lithium resources from these countries, who has lithium.

South America is going to be the largest manufacturers of lithium extracted from brine as they lack in the expertise of car manufacturing; they cannot make quality car. But they can, there may be enough industries to extract lithium and export it to the countries of the car makers the makers of the storage battery. Sodium ion battery as you know is there is only one known company Faradion in UK. Lithium ion battery manufacturers are mostly in Asia, Korea, China, Japan, the dominate; they have the precursor material as well, so that is the advantageous part.

Australia and part of Asia and US, who would achieve a balance between the production and consumption, they can make cars and they have the resources. But Europe will be the sufferer and we are the sufferer as well. And Russia and China, they are going to be another major player in EV market, they are coming up and China is producing lot of

electric vehicles these days. So, that is the prediction based on the current data as far as the resources are concerned.

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So, if you see the price of lithium carbonate, you can see that starting from we have increased the span here. But current price already I showed you in my last lecture. So, as you can see, this has increased; this is remember part ton price is part ton of the lithium resources. So, it has shoots up it has a shoot up 2005 and then, more or less, it is stabilized. So, the part is average is you can because sometimes this is high, sometimes it is low. So, the average price is something of this kind. So, it is coming around 6; roughly about 6 dollar per kg. And this is being stabilized.

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Brief estimate of the battery cost relative to the cost of lithium

- 18650 cells are universally used in portable computers. It contains 0.8g of lithium for a capacity of 2.7 Ah. At \$6/kg, the cost attributable to lithium is less than \$0.005.
- For a 9 cell battery, the cost of the lithium (7.2g) is \$0.043. It is a tiny proportion of the final cost.
- For an average sized electric vehicle, the mass of lithium needed to create a battery pack is around 3 kg. At \$ 6 /kg, the cost of lithium works out at less than \$ 20.
- Very small part of the final cost of the battery pack is contributed by lithium.
- Finally, in case of geographical tension and/or a demand that is greater than the factories' capacity to provide lithium, an increase in the cost of this metal would not have a prohibitive impact on the cost of a battery pack.



So, this already I have described, but I want to repeat it once again just to tell you that the use of lithium in a lithium ion battery that is indeed marginal with respect to the cost of the cell itself and this is applicable for the cylindrical cell and this is also applicable to a bigger battery module, although the cost will here, it will increase because the use of BMS, the thermal management system, a good packaging system. So, that will come into picture.

In case of the laptop battery or in case of the prismatic cell, which we use for our mobile battery, we would not have any so called management system. So, there the cost will not be that much affected; but still in both the cases for bigger batteries, for individual cell or a small level couple of cells, 9 cells connected in series. So, in those kind of situation, you have always the price of the lithium is not that much, it is not very prominent as compared to the whole battery pack price. So, that is one good thing that needs to be highlighted.

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REFERENCES

- Christian Glaize and Sylvie Genies "Lithium batteries and other electrochemical storage systems, Chapter – 11 page 309 – 325 and all references (Study material)

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So, here, the actually the study material I have taken the data from various resources and try to compile it. But again, the same book you can use. These are the page numbers and remember, all the references that is cited therein. The book is a bit old, 2015 if I remember correctly. So, this 2015, what are the actual data from this literature, you can have a look and then of course, internet is another source to give you more details about this aspects.

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CONCLUSION

- Li resources – Resources, reserve base, reserves
- Li reserve – do we have enough?
- Global distribution of other battery material
- Cost evolution of lithium
- Li cost fraction of the cell and battery cost: An estimate

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So, in this particular lecture, we talked about lithium resources; resources means the reserve base and the reserves which are profitable for the extraction of lithium and we can now conclude that we have sufficient lithium considering the reserves whatever is profitable today and also, if you can consider the reserve base, then also we have more or less sufficient lithium. So, that we can cater the need not only lithium ion batteries for the consumer electronic application, but also for EV and storage.

Global distribution of the battery materials, they are highly polarized. Americas, both Americas, they have the resources; China, Australia and Russia, they have the resources; but the car manufacturing unit in Europe, they will have to either purchase the mine in other countries, if they are allowed or they will have to import the lithium resources from this country.

So, the extraction industry, they should grow-up in those countries, where resources are there and EV will anyway come into picture. Cost of evaluation of lithium, I can make a brief estimate; but more detail estimate can be found in the literature that is cited there; a detailed estimate of the use of lithium in a battery pack or in individual cell, one must look at it.

And lithium cost fraction of the cell and battery cost, this estimate is important and we are not really it is not a threat of lithium depletion in near future for the projected use in lithium ion batteries.

Thank you for your attention.