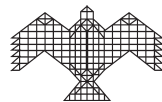






# **R & D ON RARE EARTHS AND VALUE ADDITION – THE INDIAN CASE**

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## BACKGROUND

Global and Indian interest on the role of hi-tech materials for crafting strategies that furthers a country's development and geopolitical interests has been on the increase lately. This renewed interest has come about from the various actions taken by China to establish a dominant position in the global Rare Earths (RE) industry and to leverage this position to further its global interests.

India has a fairly strong resource base in Rare Earths and with further exploration these can increase. It has also been engaged in mining and RE extraction activities for more than three decades. This makes it possible for India to become a fairly important player in the global RE industry.

In this connection a National Conference on Rare Earths Processing and Utilization-2014 was held on May 2- 3, 2014 at the Bhabha Atomic Research Centre (BARC), Mumbai. This was organized jointly by the Indian Institute of Metals, Mumbai Chapter, Rare Earth Association of India (REAI), and the Materials Research Society of India (MRSI), Mumbai Chapter. The conference included 17 invited talks and over 30 poster presentations. The poster papers were broadly classified into Rare Earths (RE) processing and application, heavy metal processing, and environmental issues during processing of Rare Earths and heavy metals.

The papers presented in the conference provide us with empirical evidence on the kind of research currently going on in India

in the field of RE. They can therefore be used to assess the current status of R&D in RE. These research initiatives can also be linked to the various components of the Indian RE value chain. These connections (or their absence) between the content of R&D and the current status of the RE Value chain in India will enable us to make inferences about the relevance of the RE R&D to the current Indian situation. It may also shed some light on the organizational and institutional bottlenecks that inhibit the development of an Indian RE ecosystem similar to those of the more advanced countries of the world.

In this brief we, the authors have examined the Abstracts of the conference proceedings<sup>1</sup> and the papers presented at the conference to make a critical appraisal of the R&D conducted within India on RE and the relevance of this R&D for India's development.

This study complements two earlier reports on the RE industry that were carried out at NIAS that have been put out in the public domain.

The first of these reports dealt with China's strategy for achieving a dominant position in the global RE industry and how it is using this position to further its national and international interests.<sup>2</sup>

The second report took a critical look at the Indian RE industry, its current competitive position vis a vis China and the United States and the role of R&D in RE for crafting a national strategy.<sup>3</sup>

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<sup>1</sup> These abstracts may not provide a complete picture of the RE ecosystem (if it exists) in the country. Nevertheless, they are indicative of the kind of research being pursued in India on the subject.

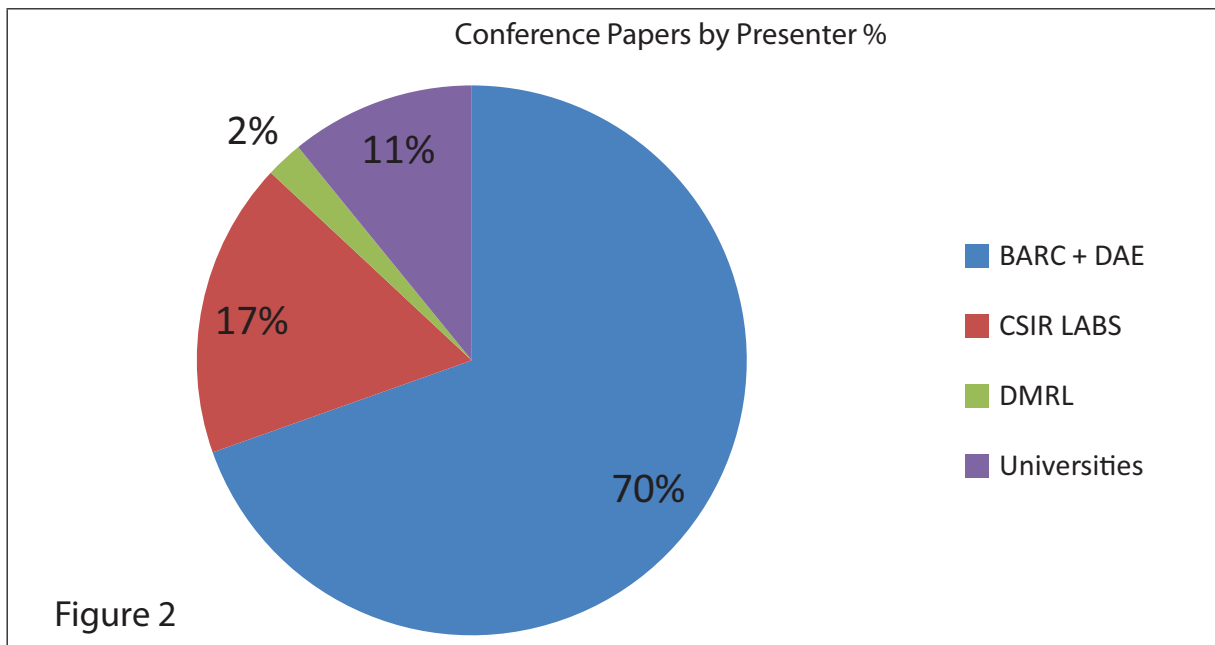
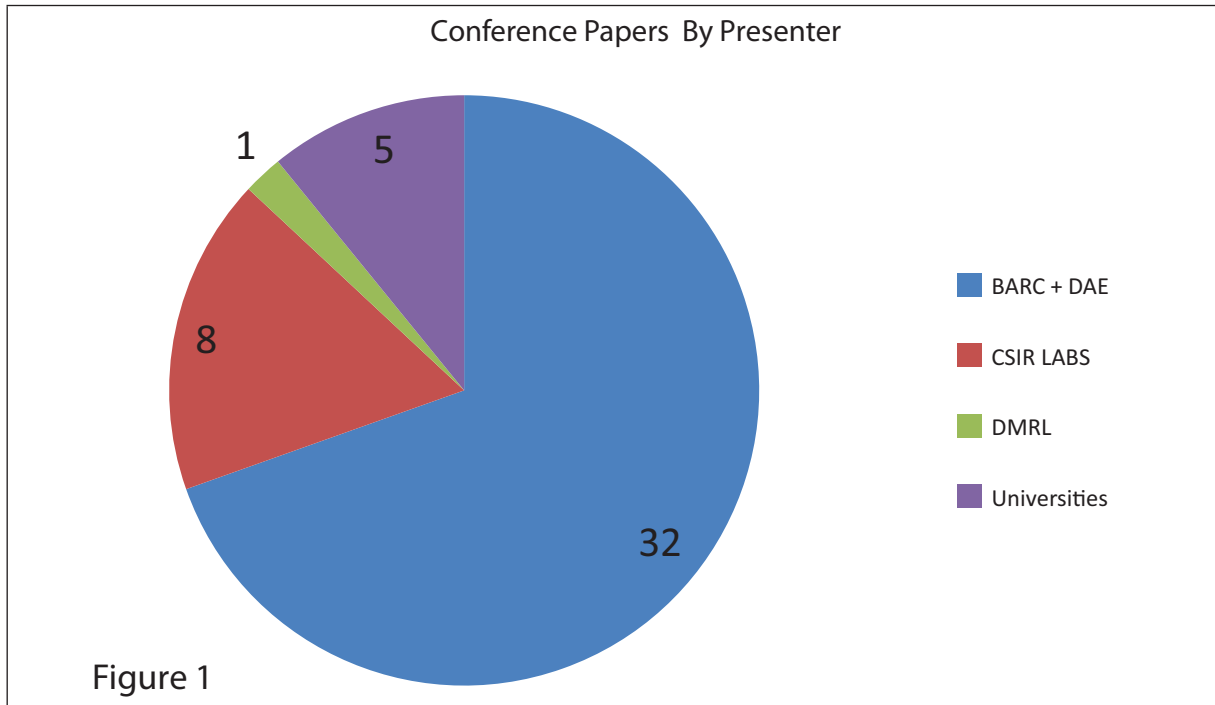
<sup>2</sup> Nabeel Mancheri, Lalitha Sundaresan & S.Chandrashekar, "Dominating the World – China and the Rare Earth Industry", International Strategic and Security Studies Programme (ISSSP), National Institute of Advanced Studies (NIAS) Report R-19-2013, April 2013.

<sup>3</sup> S.Chandrashekar, "Does India Need a National Strategy for Rare Earths", International Strategic and Security Studies Programme (ISSSP), National Institute of Advanced Studies (NIAS) Report R-18-2013, April 2013.

### THE CONFERENCE PAPERS

There were 46 papers related to RE that were presented at the conference.

Figure 1 presents the number of papers by organization affiliation. Figure 2 presents the same data in percentage terms.



A number of entities under the Department of Atomic Energy (DAE) led by the Bhabha Atomic Research Centre (BARC) accounted for 32 out of the 46 or 70% of the papers presented at the conference. These included 26 papers from BARC, two papers by the Indian Rare Earths Limited (IREL) the DAE subsidiary responsible for mining and producing Rare Earth Oxides (REO) and one paper by the Atomic Minerals Division, the entity that is responsible for exploration activities within the DAE.

Various CSIR Labs accounted for 8 or 17% of the papers presented. These included 5 papers from the National Institute for Interdisciplinary Science & Technology (NIIST), two papers from the Central Electro-Chemical Research Institute (CECRI) and one paper from the Central Leather Research Institute (CLRI). The Defence Materials Research Laboratory (DMRL) had one paper and Universities accounted for 5 or 11% of the papers presented at the conference.

## THE CONTRIBUTORS

The research in RE is dominated by the DAE and the various entities (especially BARC) that function directly under it.<sup>4</sup> Other players include CSIR labs and a single Defence Laboratory all of which come under the ambit of the S&T sector of the country.

As we can see from the data there was not a single paper in the conference that came from the private sector in India.

There could be a multitude of reasons as

to why this is so. Irrespective of the specific reason or reasons for this state of affairs, the evidence from the conference proceedings suggest that the creation of knowledge in the RE domain is confined within a few government run complexes with no major links to commercial industry. This validates the premise behind our earlier report on the Indian RE scene that there are no links between knowledge generators and users of knowledge within the Indian government run R&D establishments.<sup>5</sup> If such connections are not present, knowledge generation will be confined to laboratory investigations, journal contributions and conduct of conferences without leading to any products or services that add value.

Though there were a number of papers that indicated collaboration within the confines of a single department like the DAE almost all such collaborative work was confined to a single organization entity within that Department such as BARC. There were no papers presented that indicated collaborative activities between say IREL and BARC or between AMD and IREL all of which come under the DAE. Though this does not mean that collaboration does not take place, it does suggest that R&D knowledge generation is largely confined within a particular organization unit and that it is not directly connected to upstream, downstream or sister units.

The data from the papers presented at the conference also reveal a total absence of collaboration between the various S&T departments. There are no joint papers

<sup>4</sup> Under the allocation of business rules of the Government of India all activities related to Atomic Minerals come under the DAE. Since RE materials occur along with uranium and thorium materials in India it is logical for the DAE to have pioneered its mining and production.

<sup>5</sup> "Though India has a reasonable base in R&D especially within the public sector mission organisations its record in converting technology into viable products and services has not been very good", Reference 3 p 13.

between any of the units operating under the DAE, CSIR and DRDO. The speaker from DMRL however, did say that DMRL has been collaborating with the Department of Space (DOS). In an earlier report we had mentioned that one of the successful collaborations that took place within the Indian S&T government sector was the development of RE permanent magnets by DMRL and VSSC for use on Indian rockets and satellites. Though the magnets were developed and flown they used imported RE material rather than material processed and supplied by IREL. This seems to suggest the absence of any kind of coordinated activity between the various government S&T establishments especially in an area that is economically and strategically important.<sup>6</sup>

*The evidence from the analysis of the papers presented at this conference validates this premise of an absence of a national level strategy that is strong enough and forceful enough to connect the various largely public sector S&T activities to desired national capabilities and national aspirations in the economic or strategic domains.*

## THE CONFERENCE PAPERS AND THE RE VALUE CHAIN

Figure 3 provides an overview of the typical RE Value Chain of an industrialised country.

Based on the contents, the papers presented at the conference were grouped according to their contributions to the value chain activities.

There were single papers (2% of the papers) on exploration and mining. Together they account for 4% of all papers.

The production of basic Rare Earth Oxides (REO) accounted for 3 papers or 7% of the total.

RE separation had 6 papers (13%) and the preparation of various RE compounds, metals and powders accounted for 7 or 15% of the papers.

23 or 50% of the papers were related to the use of RE for the production of various Value Added products that includes magnets, lasers, cathodes, phosphors, catalysts, batteries, pigments refractories and even turbine blades.

There were also 5 papers (11%) dealing with safety environment and recycling issues.

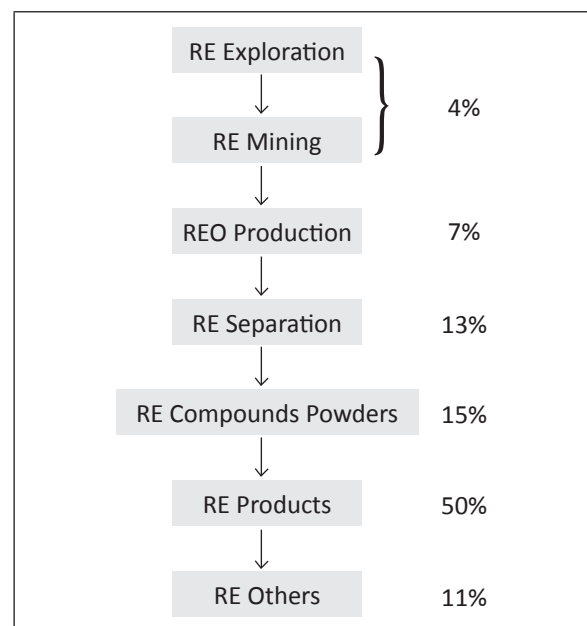


Figure 3

## Exploration

The two major agencies involved in exploration activities in the country related to RE are the Atomic Minerals Division (AMD) of the DAE and the Geological Survey of India (GSI). The paper presented at the conference

<sup>6</sup> More details of this are available in Reference 3 pp 4-6.



was by AMD which provided an overview of the current status of the exploration activity in the country. GSI however did not present any paper in the conference.

The evidence based on our earlier reports suggests that there is a major need to expand the exploration activities related to RE resources in the country. R&D and the acquisition of related knowledge and equipment for the speeding up of this process would appear to be a very relevant activity in the value chain depicted in Figure 3. The absence of papers from GSI and the fact that only a single review paper was presented suggests that these are not viewed as very important by the research community. The establishment of a comprehensive data base related to the country's RE resource base does not appear to be a major priority area for the strategic community in India.

### **Mining**

Apart from IREL other entities mine the beach sands for various minerals including RE. Mining of the beach sands and their separation into various atomic and other minerals has been going on for more than 50 years and is a mature activity in the country and may not require any major R&D activity. The single paper presented relates to improved characterization of RE occurrence in beach sands that could increase the efficiency of recovery of RE and the other constituents of beach sands.

### **REO Production**

There are three papers related to the production of REO in the conference proceedings. Two of them are from IREL and one is from the Uranium Extraction Division of BARC. One of the papers is an overview of the global supply and demand

for RE whilst the other two deal with processes for improving the separation of the various constituents of the beach sands. REO production in the country has been going on for a fairly long time in the country and is a mature activity. The papers suggest improvements to these well-established processes and appear to be a relevant R & D activity.

### **RE Separation**

There are six papers dealing with RE separation. Except for one paper from IREL all other papers are from BARC labs. Though IREL has been producing REO mainly for the export markets it has not been engaged in a major way with their separation. Such separation into individual RE elements and compounds would add considerable value. R&D related to RE separation therefore appears to be very relevant research in the current context.

Since there was no collaborative paper from IREL and BARC, it is not clear whether knowledge generated at BARC is transferred to IREL. This is significant because RE separation is an important activity of IREL and R & D on this will go towards value addition of RE material export.

### **RE Compounds and Powders**

There were seven papers related to the production of various RE compounds and powders and especially nano powders. These are all related to the use of special forms of RE directly in various applications. Currently IREL is not producing any of these forms of RE in any scale. Their production would enhance the value addition to the basic REO being produced by IREL and can therefore be termed as very relevant R&D activity.

## RE Products

The 23 papers (50%) under this category cover a large number of products and industries spanning the spectrum from the more traditional industries such as pigments, refractories, catalysts and alloys to more modern industries such as lasers, magnets, phosphors and other hi-tech products. While all of them may deal very rigorously with the knowledge aspects of the use of RE in various products the relevance of much of this R&D is questionable. The reason for this is simply that the knowledge creation part, which is largely within the confines of the major public sector technology oriented mission organisations, is not connected in any way with industries who are the potential users and beneficiaries of this knowledge creation process.

As we had mentioned earlier the absence of any papers from the private industry in the conference indicates that industry in India is either not aware of RE based product possibilities in the many established industries in the country or not interested in research related to RE for the products and services that they currently offer. Unless this gap between the production of RE material and their use in various products is bridged the relevance of much of the product oriented RE research becomes questionable.

## RE Others

There are five papers under this category. Three of these papers deal with issues of radiological safety during RE extraction and RE waste disposal. These would be directly connected to RE operations and can be considered relevant to the current context of the Indian RE industry.

Two of the papers deal with REE recoveries from waste streams. Here once again the R&D may appear to be relevant especially with regard to the use of fly ash waste for REE recovery. The absence of any link with the user suggests that the research may not result in any concrete benefits.

## The Indian RE Ecosystem in the Global Context and the Role of R&D

In our earlier report we had traced the evolution of the global RE Ecosystem through its various phases.

The report also placed the current competitive position of the Indian RE industry in the global context especially with respect to the current Chinese and US positions. The figure is reproduced below for ready reference.<sup>7</sup>

The need for various RE based products is likely to grow for some time globally and this offers a lot of value addition opportunities in the product space for RE materials for India.<sup>8</sup> However, there are a number of structural problems within the Indian RE ecosystem that have inhibited the evolution of a well-connected industry that spans the spectrum from exploration and mining to the production of RE materials and various products based on RE. The US achieved such a capability in the 1970's and China achieved such a capability in the early 1990's.

We had assessed India's position in the global eco system very optimistically at the ascending portion of the S – curve. We also mentioned that India could use its large resource of RE and its prospects for economic growth to improve its competitive position.

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<sup>7</sup> S.Chandrashekar, "Does India Need a National Strategy for Rare Earths", International Strategic and Security Studies Programme (ISSSP), National Institute of Advanced Studies (NIAS) Report R-18-2013, April 2013.

<sup>8</sup> India ranks third in the availability of RE resources. See table 4, Ref 2.

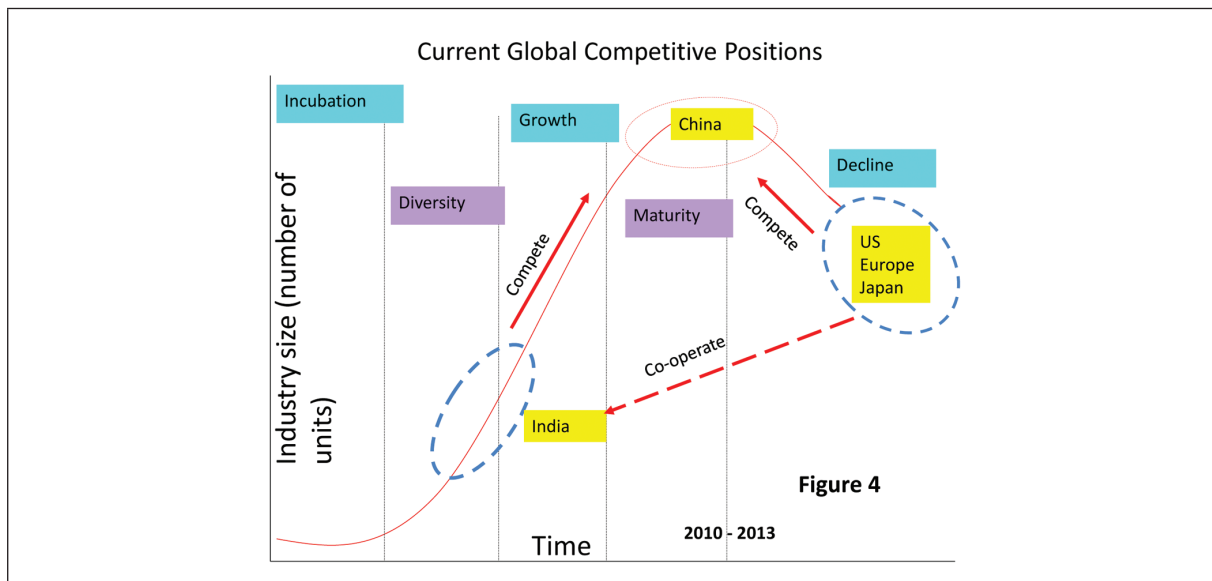


Figure 4

Analysis of the papers presented at the Conference provides us with additional information that helps us to refine India's competitive position within the global RE ecosystem.

The papers in the seminar seem to suggest that while there is academic interest in RE based products, there is a total absence of any kind of industrial linkage in all these efforts.<sup>9</sup> Most of these R&D efforts therefore are not likely to result in any kind of tangible economic benefit arising from industrial activities. Based on a simple count of the papers at least 50% of the R&D effort will be wasted.

Research pursued in RE mining, RE separation and production of different RE materials (37% of the papers) appears to be relevant and could add value to IREL's largely export oriented output. However, while IREL has been exporting RE materials

to the global RE industry, value addition to these materials especially via products has been totally absent in the country. Further, users of RE materials in the strategic sectors, currently import RE materials for their production of RE permanent magnets. Thus even within the confines of government run mission organisations there is a visible disconnect between various users such as DOS, DRDO and the potential materials supplier IREL. This is clearly evident from the seminar proceedings which show no indication whatsoever of any kind of collaborative research between these entities.

In the absence of such links much of this research effort may not result in great benefits to the Indian defense sector. However, unlike the case of product development research this research may help IREL realize more money from its exports.

<sup>9</sup> In 1996, DMRL, Min. of Defence, India transferred the technology of making Nd-Fe-B permanent magnets to Mishra Dhatu Nigam Ltd (MIDHANI). This indigenous development was supported by TIFAC, DST. (See Commercialisation of Home Grown NdFeB permanent Magnet Technology, Technical & Closing report submitted to TIFAC by DMRL, Hyderabad for more details). It is interesting to note that MIDHANI was not represented in the seminar. TIFAC has also brought out a report "Handbook on Rare Earth Occurrences Production & Application" and "Rare Earth Metals in 2002". Obviously these efforts have not kindled any interest in the Indian industry.

The analyses also substantiate our earlier findings that there is an absence of a strategic direction in the current research efforts associated with RE materials. As a consequence India does not have any major presence in the global RE ecosystem except as a limited supplier of basic RE materials

The papers presented at the seminar also emphasize India's inferior competitive position in the global RE industry. Given the current realities of research in RE and its links with products, the Indian RE scene can be picturised as in figure 5.

The absence of any real links between research and use places the Indian RE industry within the incubation phase rather than in the early growth phase as indicated in our earlier report.

Our earlier report shows that the global RE industry is now in a mature state and the numbers of major breakthroughs especially in the product space are coming down. China's dominance of the entire RE Value Chain which also includes a significant R&D component will ensure that it will be able to capitalize on any new developments related to RE whenever and wherever such developments happen.

On the other hand Indian position in the global RE scene is even more inferior than what we had projected in our earlier report. The absence of any links between R&D in RE and RE products in industry and the strategic sectors of the Indian economy will make it particularly difficult for India to catch up with the rest of the world.

The challenge of moving from the incubation into the growth and mature phases is not a trivial one and requires a substantial change in direction and strategy. In other words, India still has to go up the S curve if it wants to be a global player in the RE eco system and this needs to be done sooner than later.

If India can put together a national strategy for RE and bring about relevant coordination between research entities, the mission organisations and RE product producers in industry there is still some hope that India can become a player of substance in the global RE industry. This will take some time to achieve and will require considerable investment in money, time and effort. This will also require significant improvement in national managerial capabilities that cut across mission organisations. There is

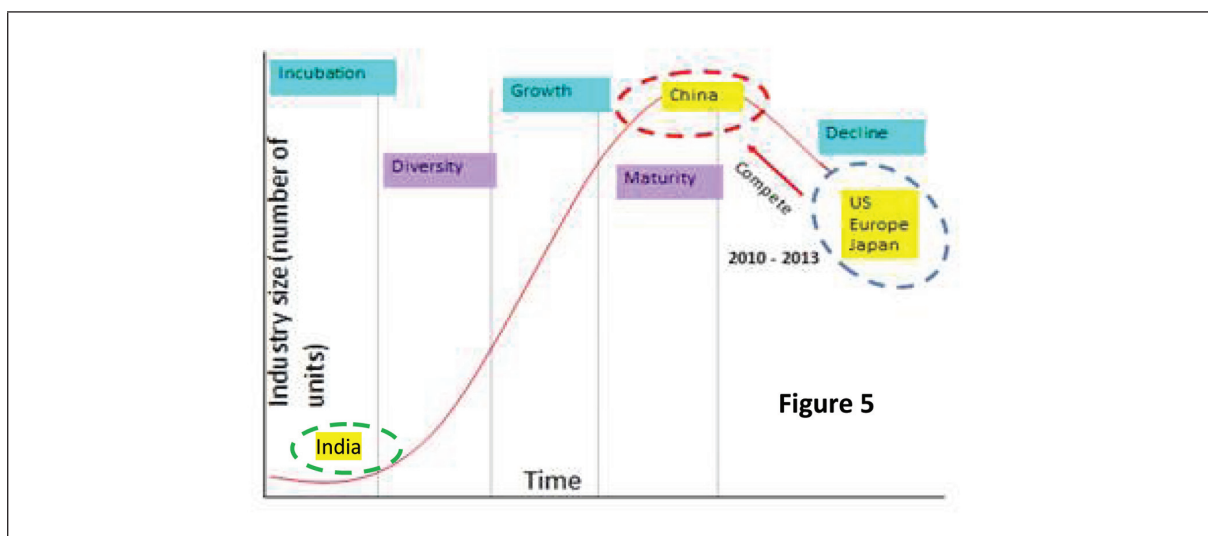


Figure 5

also a need for strong leadership in these organisations to put these elements together. If India is not able to put together and implement such a national strategy it runs the danger of continuing to be a low cost raw material supplier to the global RE industry. Given its poor track record of linking research with products it seems most likely that India will continue to supply RE raw material to the global RE industry.

## CONCLUSIONS

There seem to be two distinct components of the Indian RE ecosystem that appear to be unconnected with each other.

The first component of this Indian RE ecosystem relates to DAE activities for producing basic RE materials that go into various downstream industries. From Figure 3 this includes all activities from exploration to the production of REO as well as various RE metals and compounds. This component of the Indian RE ecosystem is directly linked to the global RE industry as a low cost supplier of RE materials. It is largely exercised through IREL exports to the global market place. It is unconnected to the needs of the Indian strategic community and is also unconnected to any users in Indian industry.

One would assume that the value addition of RE would begin at IREL and significant R & D both in RE separation and RE downstream materials production would emerge from there. This is not so.

From the papers presented at the conference it appears that IREL which is

responsible for mining and producing basic REO materials largely confines itself to low level mining and RE extraction activities only.

Most of the knowledge generated for RE separation and downstream materials production is taking place within various BARC labs. One could postulate that with a proper strategy in place such research would move into IREL leading to value addition. The evidence from the papers as well as public knowledge about IREL suggests that this is not happening. This is indicative of fundamental structural problems in the DAE, BARC, IREL relationship that will come in the way of any value addition activities.

The second component of the Indian RE ecosystem comprises a lot of product oriented R&D both within DAE and some of the S&T public sector mission organisations. The available evidence suggests that even within this R&D ecosystem the connections between raw material production and the use of such materials in products required by the strategic sectors or by Indian industry are weak or non-existent.

The major missing component in the current RE ecosystem is of course the absence of any real linkages between the RE research community and Indian industry. As long as this situation is not remedied the Indian RE industry will continue to be a low cost supplier to the global RE industry. If these fundamental structural issues are not addressed focusing R&D on the development of products will be a wasted effort with no real economic benefits.

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