Final Report

EVALUATION OF THE SCHEME 'PROMOTION OF R&D IN IRON AND STEEL SECTOR'

Submitted to

सत्यमेव जयते

Ministry of Steel
Government of India

By

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CONTENTS

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ABBREVIATIONS

BAT	Best Available Technology
BF	Blast Furnace
BHJ	Banded Hematite Jasper
BHQ	Banded Hematite Quartzite
BMQ	Banded Magnetite Quartzite
BOF	Basic Oxygen Furnace
CCS	Carbon Capture and Storage
CDQ	Coke Dry Quenching
CIMFRI	Central Mining and Fuel Research Institute
DOE	Department of Expenditure
DRI	Direct Reduction of Iron
DST	Department of Science &Technology
EAF	Electric Arc Furnace
EFC	Expenditure Finance Committee
EIA	Energy Information Administration
EOF	Electric Oxygen Furnace
ERA	European Research Area
ESTEP	European Steel Technology Platform
FP	Framework Programmes
GHG	Green House Gases
HPSR	Hydrogen Plasma Smelting Reduction
IIT	Indian Institute of Technology
IMMT	Institute of Minerals & Materials Technology
KIOCL	Kudremukh Iron Ore Company Limited
LOI	Loss on Ignition
NEDO	New Energy & Industrial Technology Development Organisation
NML	National Metallurgical Laboratory
PAMC	Project Approval and Monitoring Committee
PCI	Pulverized Coal Injection
POSCO	Pohang Iron and Steel Company
PPP	Public Private Partnership
PRC	Project Review Committee

RD	Research and Development
RDCIS	Research & Development Centre for Iron & Steel
RFCS	Research Fund for Coal and Steel
SAF	Submerged Arc Furnace
SAIL	Steel Authority of India Limited
SDF	Steel Development Fund
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
SWOT	Strengths, Weaknesses, Opportunities and Threats
TOR	Terms of Reference
TRT	Top Recovery Turbine

INTRODUCTION

The purpose of R&D is to enhance the knowledge and expertise, which would lead to development of new or improved products, improved processes, cost reduction or meeting the continuously changing customer and environmental needs. The extent of R&D undertaken generally depends upon the Industry, the technological field in which the company is based and the extent of competition. Iron and Steel sector faces a lot of challenges in this regard. Despite recording the highest growth rate of 4.3 per cent in 2012 (Report of World Steel Association, 2012), among top five major steel producing nations, India is still the fourth largest producer of steel in the world. It aimed to achieve second position in crude steel production by 2015 (Annual Report 2011-12), which it seems has been delayed as Annual Report 2012-13 mentions to achieve this position 'soon'. Increased production is also required to satiate the developmental needs. There are other concerns also like energy consumption, reducing carbon emissions, etc. Towards these objectives, it is very necessary that sufficient attention is paid towards R&D.

However, in India, expenditure on Research and Development in iron and steel sector is fairly low and is mainly contributed by the public sector, despite the fact that more than 75% of the production is in the private sector. While the average expenditure on R&D is around 1-2% of the sales turnover in the advanced countries, it is very low in the range of 0.15-0.30% in India. There has been a scheme for promotion of R&D from the interest proceeds of Steel Development Fund. However, the expenditure on R&D remains abysmally low. To provide thrust to such efforts, the scheme under study was launched by the Ministry of Steel during the 11th Plan period from the Plan fund. The scheme was launched to promote R&D in thrust areas. The financial assistance is to be given to both public and private sectors that include the research and academic institutions.

Objectives of the R&D Scheme

The objective of the scheme is to pursue R&D under the three broad areas:

- Development of innovative/path breaking technologies for utilization of iron ore fines and non-coking coal.
- Beneficiation of raw materials like iron ore, coal etc. and agglomeration.
- Improvement in quality of steel produced through the induction furnace.

Eight research projects were sanctioned during the 11th Plan. While one project has been completed, the other projects are yet to be completed. The list of the projects is as given below:

Table 1: Names of the projects and respective research organizations

Sl. No	Name of the Projects	Lead Agency	Partner Institutions
1	Improvement in sinter Productivity through deep beneficiation and agglomeration technologies	NML, Jamshedpur	IMMT, RDCIS IIT Kanpur
2	Alternate, complementary route of Iron / Steel making with low grade iron ore and non coking coal	NML	IMMT, CIMFR AMPRI, RDCIS
3	Production of low phosphorus steel using DRI through induction furnace route	NML	NISST
4	Development of futuristic Technology of carbon free iron production. Hydrogen Plasma Smelting Reduction	IMMT Bhubaneswar	-
5	Beneficiation of iron ore slimes from Barsua and other mines in India	RDCIS, Ranchi	-
6	Development of pilot scale Pelletization technology for Indian ore with varying degree of fineness	RDCIS	IMMT, NML IIT-Kharagpur
7	CO2 abatement in iron & steel production by process optimization	IIT-Kharagpur	RDCIS
8	Production of low ash(10%ash) coal (coking & non Coking) from high ash Indian coals including desulfurization of high sulfur North East coal	IMMT	RDCIS, CMPDI NML, NEIST

The scheme is being continued in the 12th Plan.

The Study

The study has been conducted by the Indian Institute of Public Administration at the behest of the Ministry of Steel. In line with the direction from Department of Expenditure, the Ministry decided for evaluation of the scheme to assess the effectiveness of the Scheme. The terms of the assignment as given by the Ministry for this study are given as below:

a) Analysis of objectives of the scheme vis-à-vis the national perspective.

b) To evaluate the Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the Scheme.

c) To study and evaluate the performance of the scheme by taking into consideration all objectives of the scheme and interventions/support measures provided, so as to bring in further improvements in implementation of the scheme.

d) To study and assess to what extent the various R&D projects under the scheme have yielded results vis-à-vis the objectives of the individual R&D projects as well as the overall objectives of the scheme.

e) To study the utilization of funds by the institutions vis-à-vis sanctioned projects/scheme guidelines and whether the funds have been utilized for the purpose for which it has been given.

f) Few case studies to be prepared while evaluating the scheme, in terms of the success and failure and analysis of the reasons for failure & success.

g) To give suggestions and recommendations for further improvement in the scheme.

h) To recommend justification for continuation of the scheme or otherwise.

Methodology

As per the ToR, as mentioned above, the focus of the study is both on the process as well as impact of the scheme. While the scheme has been in operation since 2009-10, the research projects could start only in 2010-11, so the impact assessment is to the extent information available on the progress made under the projects. As already indicated, only one project has been completed so far and all others have been given extension. The process evaluation has been done with a view to improve the effectiveness of the scheme, if the scheme is continued. Analysis of the scheme has been done on the basis of data collected from various sources.

For the purpose, information was collected from both primary and secondary sources. Reports and documents, minutes of Project Approval and Monitoring Committee (PAMC), Project Review Committee (PRC) etc. were collected from the Ministry. Interactions were also held with all the stakeholders. The stakeholders included officials of the Ministry, research institutions engaged in the eight research projects, members of the PAMC and PRC and private sector officials.

The visits to the research institutions were undertaken for interacting with all project teams as well as collecting data about the specific research projects. Thus the study team visited Institute of Minerals & Materials Technology (IMMT), Bhubaneswar, National Metallurgical Laboratory (NML), Jamshedpur, R&D Centre for Iron & Steel (RDCIS), Ranchi and Indian

Institute of Technology (IIT), Kharagpur. These four institutions are the lead institutions for the eight projects. Visit was also made to Central Mining and Fuel Research Institute, Dhanbad, which is a partner institution in one of the projects. The purpose of visiting partner institution was to assess the effectiveness of the coordinating and monitoring mechanism. Interactions were held with the members of the project teams with the help of open ended semi-structured questionnaires, while the discussions with the heads of the institutions in three places (IMMT, RDCIS and NML) were largely focused on policy issues including broader framework of the scheme and benefits from the projects.

Indicators have been identified for assessing the projects, which include initiative, adherence to time-lines, coordination and monitoring mechanisms with partner institutions, patents (domestic/international), papers published (national/international), papers presented in the seminars/conferences, industrial linkages for pilots / commercialization at later stages and financial performance, all relating to their respective projects.

Discussion on each project has been done separately also to understand the various issues. The framework for discussion on each project is:

a. Objectives of the research project
    i. Which problem/s does it study/solve
    ii. Relevance of the problem
    iii. What is the current practice in the industry
    iv. Efforts being made internationally to address the similar problem
b. Performance of the project- both physical as well as financial
c. SWOT analysis
d. Assessment of the project

Information has also been gathered from other sources like relevant research articles in journals both domestic and international, internet and discussions with experts.

Appropriate research tools and techniques have been used to analyze the data. The analysis is both qualitative and quantitative.

PART A

A.1: Recent Pattern of Growth of Steel Sector in India

Production and consumption of steel are important indicators of economic development of any country. In India, the per capita steel consumption has risen from 38 kgs in 2005-06 to 59 kgs in 2011-12. Crude steel production grew at 8% annually [Compounded Annual Growth Rate (CAGR)] from 46.46 million tonnes in 2005-06 to 73.79 million tonnes in 2011-12. Production for sale of finished steel stood at 73.42 million tonnes during 2011-12 as against 46.57 million tonnes in 2005-06, an average annual CAGR growth of 7.9%. On the other hand, China is not only the largest producer of steel (627 million tonnes), it is also the largest consumer of steel (576 million tonnes) followed by the United States and India. Steel is a major ingredient in several industries like construction, automobiles, etc. Apparently, the world steel production will continue to grow. India is also keeping up with the pace. The liberalization of industrial policy and other initiatives taken by the government have given a definite impetus for entry, participation and growth of the private sector in the steel industry. While the existing units are being modernized/expanded, a large number of new steel plants have also come up in different parts of the country based on modern, cost effective, state of-the-art technologies.

Significance of R&D

Focus on productivity and sustainability of the steel sector involves continuous efforts in R&D activities. In this regard it is important to note that the industry is also one of the most polluting industries contributing huge amount of CO_2 in the atmosphere, thus affecting the environment adversely. There are technologies which primarily aim at improving energy efficiency and reducing environmental pollutions. The information about them is available in national /international publications like State of Art Clean Technology Hand Book of APP- Steel Task Force, New Energy & Industrial Technology Development Organisation (NEDO) Handbook and EU Best Available Technology (BAT) Handbook. The Ministry admits that the industry is well aware of these technologies but actual on ground implementation is lacking. The secondary steel sector, however, lacks knowledge about BATs relevant to the sector. So the Ministry advises dissemination of knowledge in this regard and wants everyone to adopt these.[1] Despite the above, the area remains a priority area for R&D for further cutting down the environmental pollution.

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[1] A Roadmap for Research & Development and Technology for Indian Iron and Steel Industry, 2011. Ministry of Steel, Government of India

Thus, the increase in production as well as environmental concerns would require continuous investment in R&D by all the stakeholders. Most of the top rank steel companies pursue extensive R&D programmes with substantial investments so as to remain globally competitive. R&D scenario in steel companies abroad particularly in China, Japan and South Korea is quite different as compared to India. Not only the companies are equipped with full-fledged in-house R&D laboratory, they also have important tie-ups with external laboratories, academic institutions etc. with large outlay of funds earmarked for R&D. Naturally, annual R&D investment there is very high and reportedly varies in the range of 1-2% of their turnover.

For example, world's top ranked company, POSCO, South Korea invested US $ 359 million (Rs.1800 crores approximately) nearly 1.4% of its turnover in 2007. The success story of POSCO is a result of extensive research directed by the top management. Even, relatively, lesser known China Steel Corporation, Taiwan, a 12 million tonne integrated steel plant, spent US $ 40 million (Rs.200 crores approx.). R&D investment by some of the companies abroad is given below in the table:

Table 2: R&D Expenditure of Global Steel Companies as percent of sales turnover(%)

Company Name	Country	2008-09	2009-10
Nippon Steel	Japan	0.9	1.0
JFE	Japan	1.1	1.1
POSCO	South Korea	1.2	1.3
Thyssen Krupp	Germany	0.6	0.7
KOBE Steel	Japan	1.4	1.4
Arcelor Mittal	Luxembourg	0.2	0.4
Sumitomo Metal	Japan	1.2	1.2
Bao Steel	China	1.2	1.7

Source: A Roadmap for R&D in Iron and Steel Industry, GoI

Compare this with R&D investments made by the companies in India:

Table 3: R&D investment (in Rs Cr and as % of turnover) in India

Company	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12
SAIL	76.8(0.20%)	101.86(0.22%)	118.2(0.24%)	107.3(0.24%)	132.14(0.28%)	134.45(0.27%)
RINL	11.7(0.13%)	17.9(0.17%)	17.4(0.16%)	12.7(0.12%)	14.34(0.12)	20.29(0.14)
Tata Steel	33(0.24%)	42.2(0.21%)	39.2(0.20%)	48.8(0.21%)		
JSPL	2.76(0.07%)	3.36(0.06%)	3.14(0.04%)	3.3(n.a)		
Essar Steel	9.9(0.11%)	13.77(0.12%)	15.14(0.12%)	18.4(0.17%)		
JSW Steel	--	14.86(0.13%)	12.28(0.09%)	9.14(0.06%)		

Sources: A Roadmap for R&D in Iron and Steel Industry, GoI and Annual Reports of MoS

Major investment in R&D in India in the sector is by the two largest producers in the country- SAIL and Tata Steel. But the quantum is far less than the global standards. Moreover, the R&D in India is mostly plant specific and focus on the development of new technology or processes has rather been low. Till now, we had not given much priority to our raw materials also for R&D.

The R&D work done in Europe, Japan and even in the United States does not concentrate so much on raw materials as they import them as per their requirement. They have focussed on the issues depending on their priorities. For example, they have focussed a lot on the environmental concerns or energy consumption etc. As focus of iron/steel making is shifting to developing countries like China, India and others, they need to invest in R&D as per their priorities. India has reserves of raw materials of varying qualities and so it is logical that we develop our own solutions to our perennial problems on priority as a National Policy. A roadmap for Research & Development and Technology in the sector was prepared by the Ministry of Steel with the aim to highlight the gaps in R&D and Steel Technology and sensitize the steel industry to draw suitable action plan/strategy to invest on R&D and technology upgradation programme.

National Perspective

Iron and steel sector has been one of the priority areas for our planners and policymakers since independence. Huge capacities were created both in the public sector and the private sector. Today, India is aiming to become the second largest steel producing country soon.[2] All the documents indicate that steel industry has the potential to grow at a rapid pace. It may double its capacity in less than ten years.

[2] Annual Report 2012-13, Ministry of Steel, Government of India

Table 4: Estimated Demand and Capacity Creation

(in million tones)

Sl. No.	Item	2010-11	2016-17
1.	Demand for Carbon Steel	62.14	108.3
2.	Demand for Alloy/Stainless Steel	3.47	5.0
3.	Total Domestic Demand for Steel	65.61	113.3
4.	Net Export	(-)3.34	2.0
5.	Production (net of double counting)	62.27	115.3
6.	Category-Wise Consumption (Carbon Steel)		
	Total Long	31.16	54.3
	Total Flat	30.99	54.0
	Total Carbon Steel	62.14	108.3
7.	Total Requirement of crude steel	-	142.3
8.	Likely Capacity of Crude Steel	78.0	149.0

Source: *Report of the Working Group on Steel Industry for the Twelfth Five Year Plan (2012 – 2017)*

However, the challenge is "to sustain growth, avoid obsolescence of existing facilities and improve the newly adopted technologies". The Report of Working Group for 12th Plan says "A concerted effort to synergize the design and manufacturing capabilities and in house R&D would be critical to meet the above challenge". It further says that strategy to overcome these challenges would be to develop 'new technologies/process/product through own research'. "This will require resources in terms of funding, talented manpower and well equipped laboratories and all of them need to be developed to achieve a robust Research and Development process."

The National Steel Policy 2005 places emphasis on R&D to create state-of-the-art manufacturing capabilities. The present investment in R&D in Indian Steel companies is very low and varies in the range of 0.15-0.30% of the sales turnover as against 1-2% in the steel companies in advanced countries (Annual Report 2012-13) as mentioned earlier. The Roadmap of R&D and Technology prepared by the Ministry mentions "Government may also create appropriate environment to facilitate growth in R&D investment". It also says that "the Government needs to encourage/facilitate development and adoption of such technologies, which are relevant to natural resource endowment of the country".

There are two ways of doing it – one as the Roadmap suggests, by creating appropriate environment and facilitate and the other is by directly supporting R&D projects. Presently, under the scheme, R&D projects are being funded directly under three thrust areas mentioned in the objectives of the scheme. Thrust areas were identified / finalized in the meeting of EFC chaired by Secretary (Steel). This identification was based on the discussions with various stakeholders engaged in R&D in the sector in January 2008[3] and subsequent feedback of Planning Commission, IFD (MOS) and others.

The first point of examination for the study therefore is to assess as to what extent these thrust areas address the concerns of the iron and steel sector in the country. In the sector two things are critical- availability and quality of raw materials and processes in steel production.

In India, two basic processes for producing liquid iron are blast furnace and DRI. Approximately 70% of the steel production is through Blast Furnace /BOF and 30% through DRI /EF route. Blast furnaces use iron ore lump, sinter and coke. Availability of high grade iron ore lump is decreasing day by day and about 70% of the present requirement of metallurgical coal is met through imports. In fact, Indian Bureau of Mines has brought down the cut off level of Fe content to 45% from earlier 60%. Therefore, there is need to focus on increased utilization of iron ore fines and non metallurgical coal. The concept note circulated by the Ministry mentions that "it is imperative for Indian Iron and Steel industry to.....develop its own technological base to maximize the consumption of indigenous available raw materials..."[4] Table given below may give an idea about the future requirements of raw materials.

Table 5: Estimated Requirement of Raw Materials and Other Inputs by 2016-17

Sl. No	Input Materials	Unit	Estimated Consumption 2011-12	Estimated Consumption 2016-17	Additional Requirement by 2016-17
1	Coking Coal	Million Tones	43.2	90.2	47.0
2	Non-coking Coal	Million Tones	35.3	28.4	-
3	Iron Ore	Million Tones	115.0	206.2	91.2
4	Natural Gas	MMSCMD	7.2	13.541	6.341
5	Ferro Alloys	In_000 Tones	2152	3673	1521
6	Refractories	Million Tones	1.29	1.97	0.69

Source: *Report of the Working Group on Steel Industry for the Twelfth Five Year Plan (2012-17)*

[3] Various stakeholders like RDCIS, SAIL, RINL, NMDC, Essar Steel, Ispat Industries, Electrotherm, Kalyani Carpenter, Jindal Stainless Steel, SIMA, MUSCO, JSPL, Monnet Ispat etc. participated in the brainstorming session. Initially it was to identify / shortlist projects to be taken up under the scheme.

[4] A 'Concept Note' was prepared & circulated amongst the stakeholders (Steel companies, research laboratories/academic institutions) in February 2009 by the Ministry of Steel to solicit the proposals.

India has 4th largest deposits of iron ore and 5th largest deposits of coal in the world. Mining of iron ore leads to 30% generation of lump and 70% fines and slimes. Today we have abundant quantity of fines and non coking coal. Fe content in the iron ore is decreasing and high ash percentage gives the requirement of utilization of fines and non coking coal in the steel industry. Draft National Policy 2012 also proposes to support intensive R&D efforts for developing techno-economically viable technologies of beneficiation and agglomeration suitable for the mineral extracted from different iron ore regions of the country.Thus R&D needs to focus on beneficiation of iron ore fines and non coking coal to ensure raw material security for the industry. So the first two objectives of the scheme relating to beneficiation and utilization of iron ore fines and non-coking coal are of utmost importance and highly relevant.

As far as processes are concerned, blast furnace route is suited for integrated steel plants of more than 2 MT capacity, which is capital intensive. There are also limited technology suppliers for blast furnace. Moreover, this process is more than hundred years old and for a variety of reasons large improvements in the efficiency of the modern blast furnace are very difficult to accomplish. The process has reached a very high level of sophistication.[5] Small and medium players are opting for DRI route of steel production. Strategy in R&D has to have long term and short term focus. R&D in BF/BOF requires a long term plan and huge investments. Comparatively, R&D investments in DRI route are less, and more appropriate for our resource base. Therefore the third objective is also very relevant. Thus it can be said that the thrust areas have been identified in accordance with our priorities.

All the stakeholders, during discussion, expressed satisfaction with the three objectives and said that these reflect the priority areas of R&D in the country given our resource base. However, some of them expressed concern that quite often the researches did not address the concerns of the industry. They attribute this to lack of constant dialogue or continuous interaction between the researchers / research institutions and the industry. One Director of a premier institute expressed the opinion that the R&D projects should reflect the concerns of steel industry. It is important to note here that in the initial stages of deliberations for the scheme, many major players from industry were involved, i.e. at the

[5] Final Report of the Technology Roadmap Research Programme, Dec. 2010. Pittsburg: American Iron and Steel Institute.

stage of identification of thrust areas and later during project proposal submission stage. However, after that their involvement has reduced. 8 projects have been funded so far. All the projects are being carried out by institutions which are government supported. There is no participation of private sector companies, though initially Tata Steel and Essar were partners in one project.

As mentioned earlier, the support or intervention of the government is through direct funding of R&D projects. However, direct funding of few research projects only, may not lead to our goal of increasing R&D investments. As per the ministry's documents also the role of the Ministry is to encourage R&D in the sector (Annual Report 2012-13). Therefore, the Ministry may consider modifying the objectives of the scheme. Both the Working Group's Report to the Planning Commission and the Roadmap prepared by the Ministry emphasize the need to increase the expenditure in R&D. While other incentives like tax incentive etc. to induce private sector player may be taken by the Ministry at the policy level, ***the study team is of the considered opinion that the objectives of the scheme may also include 'the promotion of R&D' aspect, as the name of the scheme suggests. Under the scheme, there may be a provision or we may say fourth objective for creating 'enabling environment' for 'support to R&D'.*** An enabling environment is a set of interrelated conditions – such as legal, organizational, fiscal, informational and political – that impact on the capacity of the stakeholders to engage in the processes in a sustained and effective manner.

Along with the policy measures at a broader level, it may be in the form of a facilitation mechanism at the scheme level. ***The facilitation mechanism would enable continuous engagement of all the stakeholders as well.*** It could be in the form of an Annual Conference or Stakeholder Meet, where not only the big producers but also the smaller players are invited, irrespective of the fact that whether they are involved in any of the projects sanctioned under the scheme or not. Industry Chambers should also be invited to attend this meet. Scientists and technologists should also be invited from other potential research institutes like IIT, Chennai and Mumbai, IISc, Benguluru, National Chemical Laboratories, Pune, Jadhavpur University etc. even if they are not working on Steel research *per se* at present. Besides them the other stakeholders like Ministry of Coal, Mining etc. should also be engaged for discussions. The meet should discuss the current projects- their potential, their progress etc.; and also larger issues related to R&D in the sector including the policy framework. Technology Roadmap Programme of USA held open briefing sessions of all projects each year for the benefit of the industry and the Government Department. These sessions provided a forum to help steer the projects, bring the insights of other experts to bear on research difficulties and very importantly introduce and transfer the new technology to the industry.[6] Engaging in strategic networks and knowledge sharing within R&D is hallmark of European R&D.[7] ***To operationalize this 'support', a certain percentage of the scheme budget may be earmarked.*** This is important in view of the objective of achieving the target of R&D investment to the tune of 1% of sales turnover by the terminal year (2016-17) of the 12th plan.

Though the scheme does not identify outcomes of the scheme, it may be appropriate to mention 'increased R&D investments' as outcome of the scheme. Presently, as mentioned in the Outcome Budget of the Ministry for 2013-14, the outcomes of the scheme are mentioned in terms of outcomes of the projects sanctioned and not the scheme. Outcomes are measurable. The Ministry may in consultation with experts and other stakeholders determine the tentative timelines for percentage increase in R&D investments. Right now, it may be, as the documents mention, 1% of sales turnover by the terminal year of the 12th Plan. The facilitation mechanism mentioned above, would help in this aspect. ***Another outcome for the scheme could be in terms of research leading to commercialization. While it is difficult to suggest a number, experts say that at least one out of 4-5 research projects should reach commercialization stage.*** This kind of indicator would also induce some accountability in the selection and implementation of projects and the process would become more rigorous. Stakeholders meet and other measures to engage with all the stakeholders on a continuous basis would help, as it did in USA, in transferring the new technologies to the industry.

Another dimension of the R&D is the research agenda. There has to be short term goals and there ought to be long term goals. The Ministry has done the categorization of the long term and short-medium term R&D projects. As per the classification done in the Roadmap of R&D of the Ministry, only projects having short-medium term time-frame have been taken up. The time period of 3 years indicates that. Long term projects have longer

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[6] Final Report of the Technology Roadmap Research Programme, Dec. 2010. Pittsburg: American Iron and Steel Institute.
[7] Study on the Competitiveness of the European Steel Sector Within the Framework Contract of Sectoral Competitiveness Studies – ENTR/06/054, Final report, August 2008

gestation period and need to have partnership with all the stakeholders like ULCOS in Europe, which has 15-20 years time frame and all the stakeholders are partners with commitment to contribute funds. ***It is critical to identify our research agenda in terms of operationalization of short term and long term programmes and an eye on future is very important to remain competitive in the world.*** At present none of the projects falls into the category of long term programmes. HSPR may be a technology of the future but there is no industry partner in the project. Its success now has attracted interest from industry but such partnership should have been there since beginning.

A.2: Implementation of the Scheme

Based on the recommendation of the Working Group for Iron & Steel Industry of the 11th Five Year Plan, Planning Commission allocated an outlay of Rs. 118 crore for the 11th Five Year Plan for the new scheme. Discussion with officials revealed that the scale of budget for the scheme was roughly based on the expenditures incurred on R&D from the interest proceeds of SDF. However, it could have been enhanced, as it was felt that the kitty under SDF was not sufficient to support the kind of research projects that needed to be studied under the scheme.

As per the laid down procedure, a draft scheme was prepared in consultation with the IFD, Ministry of Steel (MoS) and sent to the Planning Commission and others on 18.03.2008. The Planning Commission accorded in-principle approval on 16.06.2008. On receipt of in-principle approval from Planning Commission, a Memorandum for the Expenditure Finance Committee (EFC) for the scheme was prepared and circulated to Planning Commission and Department of Expenditure. Subsequently, the EFC under the Chairmanship of Secretary (Steel) and comprising members from Department of Expenditure and Planning Commission approved the Scheme on 21.11.2008. While approving the scheme, the EFC confirmed the three thrust areas, which are now included in the objectives of the scheme.

Formal approval of the scheme by Department of Expenditure (DoE) was accorded on 23.01.2009 wherein the DoE directed that the scheme be implemented from the FY, 2009-10. Follow-up action was taken by Ministry of Steel on receipt of the approval of DoE as per the scope of work laid down in the EFC Memorandum. For selection of specific R&D projects, a 'Concept Note' was prepared & circulated amongst the stakeholders (steel companies, research laboratories/academic institutions) in February 2009. The officials contended that it was widely circulated among the stakeholders who were engaged in the iron and steel sector and research. However, keeping in view the need to increase the talent pool / researchers in the sector, the efforts may be made to engage more potential research institutions now onwards. Scientific community in India today is very active and various research institutions and universities are doing researches sponsored by various ministries. May be some more researchers / institutions get interested in the area, even if they did not work exclusively in the sector earlier. Discussions in research institutions confirmed that people in the academia can take up the projects if there is some opportunity for funding. Otherwise also it is true and accepted principle that ***the funding determines the research agenda in any discipline or sector***.

On receipt of inputs from the stakeholders on the concept note, a meeting with the stakeholders was convened by Joint Secretary (Steel) in June 2009. In this meeting R&D Project areas were shortlisted and Lead Agencies selected. The Lead Agencies were requested to submit formal R&D proposals.

A panel of Independent Experts was constituted in July 2009 for objective evaluation of the project proposals. The project proposals were received & circulated to the Panel of Independent Experts in August-September, 2009. PAMC was constituted under the Chairmanship of Secretary (Steel) for approval of the projects to be undertaken under the scheme.

The PAMC in its first and second meetings held on 11.02.2010 & 23.11.2010 respectively, approved eight R&D projects with total cost of Rs. 143.87 crore with government funding of Rs. 111.11 crore. Subsequently, as per the decision of EFC in its second meeting held on 20.05.2011, it was decided to limit government funding upto 50% of the capital cost for commercial organizations. As a result the government funding of two R&D projects under capital head was restricted to 50% and the overall government funding for the 8 projects was reduced to Rs. 96.24 crore from earlier amount of Rs. 111.11 crore. With Tata Steel and Essar Steel opting out of the projects the total cost of the 8 projects was further reduced to Rs. 123.27 crore with government funding of Rs. 87.29 crore.

Although the scheme was initiated in 2007-08, actual R&D work on the selected R&D projects started only with effect from 2010-11 mainly due to time taken in appraisal and approval of the scheme and projects as per laid down procedure. The work of the 4 R&D projects, which were approved by PAMC in its first meeting held in Feb 2010, started in April 2010. Of the four projects which were approved by PAMC in its second meeting held in Nov 2010, the work on 2 projects started in Jan 2011 and 2 projects in December 2011.

The perusal of the notes and minutes of various meetings and the discussion with the officials reveals that a meeting of stakeholders was called and the projects were invited in this meeting. It may be noted that the SS&FA had expressed the desirability of advertisement in the print media to call for applications. The Ministry officials took this route of 'proposals by invitation' because of their earlier experience of not getting good proposals through advertisement in the case of SDF funded projects. Another argument forwarded was that the ministry was engaging with all the stakeholders since inception of the scheme and the people interested in the research in the sector knew about the scheme and were on board till then. Admittedly, the research institutions which have been awarded the projects are the ones which have expertise in the sector.

Since, all the documents of the Ministry identify the constraint of shortage of manpower due to lack of focus on the sector by academic and many important research institutions, it is important that measures are taken to induce this focus in them. Establishment of steel research centres in few academic institutions has led to desired outcome. While such centres may be established through government grants as well as the private sector grants in more institutions, the scheme also offers this opportunity of inducing more number of universities/academic institutions/ research organizations into focusing on this sector. It may be mentioned here that RINL collaborated with institutions like IIT, Chennai, IISc, Bangalore, National Chemical Laboratories, Pune, Andhra University, Vishakhapatnam and Jadavpur University, Kolkata (Annual Report 2009-10). These are potential research institutes for steel R&D. ***Research grants is a very effective incentive for all the major research institutions. Advertisement of the scheme in leading newspapers and major journals may be effective in creating the awareness.*** For example, DST, DBT etc. advertise about all their research funding schemes in all the major newspapers and relevant journals besides putting it on their websites.

Once, the projects were received from the interested researchers/research institutions, they were sent to a panel of experts for evaluation[8]. This panel consisted of eminent persons in the sector. There were guidelines for techno-economic evaluation of the proposals and comments depended upon the knowledge and expertise of the experts. However, their views were divergent on various proposals. So, these projects were discussed in a meeting, where some of them, which had similar focus/activity, were merged. Total 26 projects were received and 8 projects in number were recommended to PAMC. These 8 included some of the total projects received. One more project was received after the selection of these 8 projects, but the decision on the proposal was deferred.

A.3: Monitoring Mechanism

Monitoring of the sanctioned project has been designed at two levels. One at the organizational level, i.e. research institutions level and the other at the ministerial level.

(i) Organizational Level

There is provision of quarterly review in each project, where an internally constituted committee reviews the projects on quarterly basis. This arrangement was noticed to be very effective, as all the partner institutions participated and discussed the progress with the committee members. Since, six of the eight projects have partner institutions as collaborators; it made sure that each of them tried to adhere to timelines. It was noticed that if there was any delay, at least it was justified by the partner institutions. Probably, the peer pressure on competitiveness ensured that adequate efforts were put into the project.

The committee, since it is independent of the project team ensured that a reasonable review is made. All the members expressed satisfaction with the arrangement.

(ii) Ministerial Level

There is a provision of review of each project twice in a year by a Project Review Committee (PRC) which consists of the Jt. Secretary of the Ministry of Steel as the

[8] Panel of experts consisted of Dr. Hareesh Iddya of DSIR, Dr. S.K. Bhattacharya, former Director RDCIS and MD, DSP, Dr. Sanak Mishra, former MD (RSP) & Present CEO (Green Steel Projects) Arcellor Mittal, Dr. Amit Chatterjee, former Director, R&D, Tata Steel & presently Advisor MD, Tata Steel, Dr. A.K. Lahiri, former Professor IISc and Shri G.I.S. Chauhan Former ED, RDCIS.

chairperson and experts in the sector/subject matter as the members. Though, from the minutes of the meetings it appears that there is one PRC, the study team was informed that there are different members for each project. Thus we can say that there are PRCs according to the number of projects. So far, the PRCs have met thrice. There seems to be some gap in this review. The projects started in 2011, but so far only 3 meetings have been held. The Results Framework Document for 2012-13 indicates 14 meetings as the indicator for assessing the performance, but, it may be noted that it implies two meeting for each of the seven projects (as one project has already been completed) in a year. However, in practice, ***all the projects are reviewed in one day***. Almost all the members expressed the opinion that reviewing all the projects in one day was not appropriate. While the initial presentations on the day got discussed in detail, remaining ones had little time. Moreover, since the members of all the PRCs are present, the effective PRC is even bigger and discussion on any project involves non-members also, which consumes a lot of time. A lot of important suggestions are given, which are incorporated by the project teams.[9] While the expert opinion is valuable, the time for discussion gets reduced for other projects. The opinion of most of the persons contacted was that maximum two projects should be discussed in one day. That would give sufficient time for adequate review of each project. ***Therefore, the ministry may now onwards have reviews of maximum two projects only on a given day.*** One more important consequence of such arrangement would be that even the partner institution may make presentation about their part. At present, only the scientists from the lead institution make the presentation incorporating the findings of partner institutions. Since, the partner institutions have been roped in due to their domain expertise, it would be appropriate that they make presentation about their part.

Having two reviews a day would mean at least seven days of commitment from the Jt. Secretary, as he/she is the chairperson of the Committee. The number of days would increase when there are more projects, which is more likely as the outlay is greater in 12th Plan. It may be difficult for the Jt. Secretary to commit many days for review of projects. This brings us to the composition of the PRCs. ***The Ministry may examine the feasibility of having experts in the sector as the chairperson of PRCs.*** In fact,

[9] It is apparent from the perusal of the minutes of the meetings of PRCs that very constructive suggestions are given by the members.

in the second PRC meeting, Dr. Sanak Mishra, Arcellor Mittal acted as the chairperson in one session and Prof. B.K. Mishra, Director IMMT, in the second. Selection/appointment of members of PRC also needs to be done carefully for each project. ***The persons involved with the projects should not be the members of PRC, as this would be 'conflict of interest'***.

Periodicity of the meetings of PRC is another matter of concern. The first meeting of PRC was held on 29.11.11, second on 05.10.12 and the third on 25.03.13. So the gap between the meetings was almost 10 months and 6 months respectively. The delays were attributed to the late start of projects due to some clarifications sought by some institutions on one matter or the other. Probably, this being a new scheme, contours were not known to all. However, now onwards the appropriate periodicity of the meetings can be ensured. ***The periodicity may be determined in accordance with the timelines of respective projects***.

Frequency of the PRC meetings is also an effective indicator of monitoring. Some of the PRC members felt that frequency of PRC should be more as compared to present levels. While, most of the persons contacted including the PRC members suggested it to be twice in a year, some desired it to be on quarterly basis. Even RFD of the Ministry puts the frequency at two. ***The study team is of the opinion that in view of there being a system of internal reviews as well, the frequency of review by PRC may be twice in a year.*** At the same time, it is important to mention that DST and many other ministries of the government have provisions of annual review.[10]

Financial Reporting

The Ministry of Steel has stipulated monthly submission of expenditure by each project team. Therefore, all the institutions engaged in this scheme have to spend a lot of time on taking this information from their accounts section. The lead institutions have to do more work in this regard, as they not only need to gather this information from their offices but also from the partner institutions. It may be noted that all the lead institutions and partner institutions are autonomous bodies of one or the other government departments and therefore follow 'General Financial Rules'. In all these institutions, audit is conducted as

[10] http://dst.gov.in/r&d_funding/rdfs2.htm - General Information on Research & Development Funding Schemes of Central Government Departments / Agencies

per government norms. Hence, expenditures by project teams are as per government rules and procedures. In such a scenario, submission or requirement of monthly statement of expenditures becomes rather cumbersome for the project team members, who have to, as a result, spend a lot of time on taking these statements from their respective finance/accounts division. All the persons of these projects suggested a quarterly reporting. In Department of Science &Technology (DST) funded research projects, the submission of 'Statement of Expenditure' and 'Utilization Certificate' is on yearly basis.

The manner of expenditure incurred in R&D projects is different from normal governmental expenditures. Therefore, it is suggested that ***the Ministry may revise the guidelines for financial reporting and make it on quarterly or six monthly (preferable) basis, if not on yearly basis***.

A.4: Assessment of the Scheme

a. Physical Performance

There were no physical targets set as such under the scheme. However, sufficient projects were not sanctioned. There was Plan outlay of Rs. 118 cr. for the scheme, but the sanctioned projects were of Rs. 96.24 cr. only, including the budget for Tata Steel and Essar Steel utilizing only approx. 80% of the money available. 26 project ideas/proposals were received by the Ministry, but many were not considered. However, it also indicates that there were not enough quality proposals which could have been funded under the scheme. There can be two reasons for this- first as the documents suggest that there are not sufficient researchers and institutions which are engaged in the research in the sector, and the second may be that many potential researchers could not know about the scheme. An advertisement, as mentioned earlier, could have helped. At the same time, ***the Ministry also needs to have clear cut operationalization strategy for the agreed research agenda***. Perusal of the papers taken from the Ministry and discussion with officials indicates that it is now evolving. Research areas / technologies have been identified keeping in mind our resource base. At the same time it may be said that ***the scheme has supported R&D projects which are very relevant for the sector and the project on HPSR may turn out to be technology of the future.***

b. Financial Performance

The allocated outlay for the scheme in the 11^{th} Plan was Rs. 118.00 crores. While the formal approval of the scheme was given on January 1, 2009 by Department of

Expenditure (DoE), it directed that the scheme be implemented from FY 2009-10. Thereafter too, submission of proposal, their appraisal and approval took some time. Thus delay in implementation of the scheme was in the first place due to this being a new scheme and further delay was caused by certain financial clarifications sought by project team institutions. The clarification issues included coverage of revenue expenditure under the term 'non recurring grant in aid' as imposed by the Ministry in the sanction letter. Another issue was the limit of government funding up to 50% of the capital cost for the commercial organizations. The expenditure details under the scheme are given below:

Table 6: Budget and Expenditure under the Scheme

(in Rs. Crores)

Financial Year	B.E.	R.E.	Actual Expenditure	% Utilization over RE
2007-08	1.00	1.00	0.00	0
2008-09	18.50	18.50	0.00	0
2009-10	26.00	13.00	4.14	31.81
2010-11	35.00	29.00	27.05	93.26
2011-12	39.00	29.00	9.63	33.20
Total (11th Plan)	**119.50**	**90.50**	**40.82**	**45.11**
2012-13	44.00	26.49	24.90	90.21
Total	**163.50**	**116.99**	**65.72**	**56.18**

Source: Ministry of Steel

While the total cost of 8 projects was Rs. 123.27 cr. after the withdrawal of Tata Steel and Essar Steel from one of the projects share of Plan fund was Rs. 87.28 cr. It can be seen that the expenditure is very low. In fact, if the expenditure is calculated against the total budget outlay of Rs. 118 cr. under the scheme, it is only to the tune of 55% only. During the Plan period against the revised expenditure of 90.5, the actual expenditure was only 72% that too if we include the expenditure incurred during 2012-13, otherwise it is only 45.11%. Apparently ***the expenditure levels are low under the scheme***.

There is no budget earmarked for the administrative costs for implementing the scheme. A certain percentage may be fixed for the same. It is important because, there are expenditures which are otherwise debited to other heads, including some of it borne by the host research institutions. In the absence of the above, the Ministry is not able to provide any incentive to the experts engaged in consultations and reviews. It is a normal practice to give 'sitting charges' or honorarium to non-official members for attending various meetings, but it is not being done by the Ministry presently. ***It would be appropriate to earmark certain percentage of scheme budget for administrative expenses like organizing meetings or paying honorarium / sitting charges and also for monitoring the projects in between the reviews.***

Again, the less expenditure can be attributed to the delayed start of the scheme. However, as discussed above, there were not sufficient proposals. The Ministry had the experience of R&D projects under SDF. Since the outcome of SDF funded research was not satisfactory, the Ministry could have drawn a clear cut strategy for operationalizing research agenda based on that experience. Other support measures, outside the purview of this scheme could have also been taken like establishment of more Steel Research Centres in academic institutions.

c. Impact of the Scheme

Impact of the scheme can be assessed on the basis of the outcomes expected. There are two aspects- improvement in the level of R&D investments and achievements of the objectives of the scheme. As the projects started very late, it can be said to be too short a period to assess the impact in these terms. Here it is also important to mention that R&D investments should continue to be expressed in terms of sales turnover. This is being mentioned here as there is debate about the calculation be made as percentage of EBIT/PAT. Calculation in these terms would indicate that we are spending high percentages on R&D, which may harm R&D goals in the long term. Besides that the global practice is the calculation of R&D investments in terms of sales turnover. Both, the Working Group's Report and the Roadmap of the Ministry suggest the same.

As far as achievement of objectives of the scheme is concerned, all the projects are as per the three objectives under the scheme. From the point of view of short term and long term researches also, as per the roadmap, seven may be put in the category of short-medium term research projects and one in long term project.

A.5: Assessment of the Projects

Eight projects were sanctioned under the scheme. One of these has been completed and remaining seven have got extension and are expected to be completed in next one year or before. While brief notes on each project have been given later, a general assessment is being made here.

1. **Initiative-** The scheme has helped study of areas, which were hitherto not researched in India in some projects. For example, HPSR project at IMMT, Bhubaneswar or process optimization through computer software at IIT, Kharagpur. Though Plasma centre of IMMT has been working on various aspects of plasma for the past many years, this project could be conceived only because of the support of the scheme. In fact, this is one project, which if successful, may be path breaking in the sector. Similarly, process optimization through computer software has been attempted in other countries, but in India it would be the first time.

   In other projects, the works have built on previous researches done by researchers. However, all the projects are aimed at improving the levels recorded so far. For example, beneficiation has been a continuous focus area of research. However, in the projects sanctioned under the scheme, the focus is on raw materials which were not taken up earlier. The scheme also enabled some labs like CIMFR to get linked to Ministry of Steel. CIMFR had not collaborated on any project till now with the Ministry. The team is working on reducing ash level in non coking coal from 30% to 12%, for which the idea was given by NML. This they are doing first time. In other words, the talent pool, which is very less for the researches in the sector has increased.

2. **Relevance of the projects-** All the projects adhere to objectives of the scheme and in the opinion of independent experts, are highly relevant, as they concern our needs. Some of them, if successful, may lead to significant improvements in the processes. Thrust areas have already been discussed earlier.

3. **Performance of the projects-** One of the projects has been completed. For the other seven projects, from the minutes of the meetings of PRC, the study team concluded that the projects are progressing satisfactorily. Certain time lines have been exceeded but they are mainly due to exogenous factors. For example, Hydrogen Plasma Project

is facing design problems for its torches and smelting reactors for which the project team is not able to find indigenous solution and so are in the process of searching at the global level. RDCIS could not start work on its projects pending clarifications regarding financial aspect from the Ministry. IIT Kharagpur needs plant data for further work.

As far as financial performance of the projects is concerned, none of the 7 ongoing projects has asked for additional grant. The project which has been completed also did so within the budget. Despite extension of the projects, the expenditures are within limits. In fact, in many projects, there could be savings. RDCIS, in fact has returned some money back to the Ministry. In the project on 'Production of low phosphorous...' of RDCIS, approx. Rs. 15 lakhs have been returned to the ministry. At NML also, most of the R&D has been completed, and there is likelihood of some savings. Expenditure details of specific projects are given in specific notes.

4. **Patents, Research Papers and participation in seminars/conferences-** These are important aspects in the scientific community. To quite an extent, these are indicators of advancement of R&D. The table is given below:

Table 7: Patents, Research papers and Participation in Seminars emanating from the respective Project**

Projects	**Patents**		**Research Papers**		**Participation in seminars**	
	Domestic	International	Domestic	International	Domestic	International
Improvement in sinter Productivity through deep beneficiation and agglomeration technologies			5	1	6	1
Alternate, complementary route of Iron & Steel making with low grade iron ore and non coking coal	1*	1*	4		7	
Production of low phosphorus steel using DRI through induction furnace route	2*					
Development of futuristic Technology of carbon free iron production. HPSR Hydrogen Plasma Smelting Reduction	1*	1*				
Beneficiation of iron ore slimes from Bersua and other mines in India			1*			

Development of pilot scale Pelletization technology for Indian ore with varying degree of fineness			1*			
CO_2 abatement in iron & steel production by process optimization						
Production of low ash(10%ash) coal (coking & non Coking) from high ash Indian coals including desulfurization of high sulfur North East coal	2*		2			

*Under process
**Details of lead institutions only and CIMFR, as told to the study team by the project team members

The table gives a mixed feeling. Responses were taken only relating to the projects under this scheme. It is necessary to mention here that quite often papers are conceived later also, i.e. sometime after completion of the projects. Going by the quantum of support, there could have been more research papers and participation in seminars/conferences. Some reduction in these numbers is due to some project teams planning to file patents. The number of patents seems to be good, as at least 8 patents are being planned or are under various stages of filing. ***The PRC may include these as indicators while reviewing the projects***.

5. **Coordination and Monitoring with Partner Institutions**- The scheme has benefitted from the TEAM INDIA concept initiated by former DG of CSIR, Dr. Mashelkar, which is a CSIR network project, in which he suggested partnering of laboratories to take advantage of specialties/knowledge base of specific lab for researches having multi-dimensional focus. The coordination among various teams was found to be very effective. The basic criteria for partnerships were the expertise and willingness to contribute by the respective institutions. Since most of the scientists knew each other, the communication among them was prompt. Once the projects were conceived, the planning was done by all the team members of a project together. Some of the institutions like CIMFR had not participated in the deliberations in the initial stages at the ministerial level, were co-opted later, but after that everybody responded well. Quarterly or six monthly internal review meetings are attended by all the partner institutions.

6. **Industrial Linkages for Pilots/commercialization**- Industrial linkages were not found to be satisfactory in many cases. Since all the projects have commercialization

as their end objective, the industrial linkages should have been forged at proposal stage itself. This would have helped the research proposals to be responsive to the industry's requirements throughout the study period. Except projects being carried out at RDCIS, as it is part of SAIL, none has a confirmed industry partner. NML in one project, is going to use its own facility for pilots. Interestingly, in many projects, the industrial players had shown interest or agreed in the initial stages but there was no progress thereafter. Essar Steel had agreed initially to partner with NML in the project on Sinter productivity, but it was not taken further. RINL, Vizag was supposed to partner with IMMT for its HPSR project, but the scientists had not much interaction with the plant officials. Recently, however, after successful completion of some stages, it visited the IMMT campus to carry it further. In fact the officials of the company had just visited before the visit of the study team. For pelletization project of RDCIS also, Essar has not given any firm commitment. Thus it can be said that ***industry interface is not very effective in the projects***.

A.6: Government – Industry Cooperation in R&D

All the projects which have been sanctioned under the scheme have commercialization as their end-objectives. But except SAIL, there is no other confirmed partner from the industry in projects. It is important to understand the issues involved in getting industry, including private sector, on board. Under the present scheme, industry including the private sector players was involved in the discussions and conceptualization stage and subsequently Tata Steel and Essar became partner in one research project also. However, they withdrew at later stages as there were issues regarding ownership over patents or sharing knowledge with others and contribution of funds. As almost 75% of the steel production in the country is by the private sector, it is of utmost importance that private sector is also involved effectively in the R&D. Governments worldwide, specifically in the major steel producing countries, support R&D massively in partnership with the industry. Before we go further, we may see how the industry is engaged in R&D in other major steel producing countries.

Technology Roadmap Research Programme in USA[11]

In the United States, R&D funding was provided under a Department of Energy (DoE) Cooperative Agreement for Technology Roadmap Programme (TRP). To ensure that R&D benefitted the entire industry and not few companies, it had a 20 years vision identifying research opportunities and technological challenges and building on successful collaborative projects. Based on this vision document, a Technology Roadmap was written by 40 experts from the steel industry. To assist potential research partners outside the steel industry, the Roadmap also provided a technical discussion of the steel making process to help them tailor their research proposals to match the industry's needs. The solicitation of proposals contained a description of technologies that the industry was most interested in supporting and included evaluation criteria against which each proposal was to be judged. All solicitations were published in the *Federal Register* and distributed by email to an extensive list of research institutions including universities, national laboratories, private research organizations and individuals. The proposals were accepted from outside the US also and for technologies not described in the solicitation.

All proposals were reviewed by a board of experts in the steel industry and selected proposals were sent to the steel producers and interested suppliers for cost sharing funding commitments. Only after industry commitment, they were taken up by the government for approval and funding.

During implementation, each project had its own Project Review Board comprising representatives from the cost sharing partners and the government. Additionally, TRP held open briefing sessions of all projects for the benefit of industry. At these briefings, the project investigators provided detailed reviews of their progress, challenges, accomplishments and future plans. These projects were further reviewed by an independent panel of industry experts selected by the government.

In 10 years (between July, 1997 – December, 2008), total $38 million were invested in R&D of which the DoE provided $26.5 million (69.74%). The industrial participants provided $11.3 million cost-sharing support comprised of $3.5 million in cash (9.21%) and $7.8 million (20.53%) in the form of technical services, use of plant facilities and support

[11] Final Report of the Technology Roadmap Research Programme, Dec. 2010. Pittsburg: American Iron and Steel Institute.

personnel. The bulk of programme funds (95%) were distributed to universities, private R&D labs/organization and government national labs. Title to intellectual property is held by the industry, with the U.S. govt. having rights to royalty free use. The government also has a share in the net revenues earned by successful commercialization of the technology. The steel industry is required to pay back 150% of government cost sharing from the net proceeds of any commercialized project.[12]

R&D Support by European Commission[13]

The European Steel industry has a turnover of about EUR 190 billion, producing 178 million tonnes of steel per year in more than 500 steel production sites in 23 EU Member States. At the EU level, the steel industry has a focused strategy for supporting steel research with a unique, three-fold complementary research instrument, comprising: the Framework Programmes (FP); the Research Fund for Coal and Steel (RFCS) programme, and the Steel Technology Platform (ESTEP). Recently, the steel industry with other process industries submitted under Horizon 2020, a proposal for a new Public Private Partnership (PPP) called "Sustainable Process Industry through Resource and Energy Efficiency" (SPIRE) (budget: about 20-25 M EUR/year only for the steel part).

The Framework Programmes of European Union, also known as Framework Programme for Research and Technological Development is a major tool to support the creation of the European Research Area (ERA) with two main strategic objectives: strengthening the scientific and technological bases of industry and encourage its international competitiveness while promoting research activities.

Until Framework Programme 6, they covered five-year periods, but from Framework Programme 7 onwards it will run for seven years from 2007 to 2013 with an EU budget of some 50.5 billion Euro. Its primary aims are to strengthen the EU's science and technology base, improve the EU's competitiveness and support policy development in the EU.

Product and process related innovations and the link between research, innovation and industrial application is one of the main strengths of the EU steel industry. The RFCS proved to be a very effective tool in providing a targeted support to process and product

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[12] American Iron and Steel Institute is a trade association composed of North American Electric and Integrated Steelmakers accounting for approximately 80% of US and North American steel capacity.
[13] High-level Round Table on the future of the European Steel Industry Recommendations, Feb. 12, 2013

innovations. On the other hand, the number of projects co-funded from the R&D framework programme has been rather low.

ULCOS

ULCOS- Ultra–Low Carbon dioxide Steelmaking is a R&D initiative taken by a group of 48 companies and organisations from 15 European countries consisting of all major EU steel companies, of energy and engineering partners, research institutes and universities and is supported by the European Commission, to enable drastic reduction in CO_2 emissions from steel production. The ULCOS program is run by 10 small member of partners called the core members which contribute to the budget beyond their own work. This project is coordinated by ArcelorMittal. Apart from these core members there are 38 non member partners. The programme has two phases.

In the first phase, the budget was 75 million Euro over a 6 year period, of which the partners in the ULCOS consortium contributed 60 percent of the total cost. The European commission contributed the remaining 40 percent through its 6th Framework and the RFCS (Research Fund Coal Steel) programmes.

The second phase, ULCOS II, to be continued until 2025, was launched in 2010 and has applied to the NER-300 programme, which could bring funding of several hundred million euro. If successful, the results from ULCOS could potentially be rolled out in production plants some 15 to 20 years from now. As per Jean-Pierre Birat, ULCOS project coordinator, this is the largest research project the global steel industry has ever launched.

R&D support in China

China invests in steel R&D more than the investment made by the rest of the world put together. In China, the government directly or indirectly facilitates R&D for all sectors of economy including steel. Based on the original Soviet model, subsequently adapted and dovetailed with national needs & plans, these institutions/organizations sustain growth and retain the competitive edge of their steel industry of more than 600 mtpa. There are more than 50 R&D institutes of the kinds, namely academic and basic research linked to universities; adapted applied and industrial research institutes under institutions like CSIR in India and focused industrial R&D institutes controlled by the Ministry concerned, to cater to the sector. It can be said that the pattern of R&D funding is somewhat similar to that of

India, except the firm commitment of funds at much higher levels. It claims to contribute 6% of its sales turnover for R&D, which would be huge keeping in mind the Chinese production of steel.

NEDO Japan

New Energy and Industrial Technology Development Organisation (NEDO) was established as a semi-governmental organization in 1980 to promote the development and introduction of new energy technologies for industries in Japan reorganized as an Incorporated Administrative Agency on October 1, 2003. Since its establishment, it has undertaken technology development, demonstration projects and system improvement with the aim of improving Japan's global competitiveness and addressing social issues in an integrated manner.

Its programs and projects include promotion of private sector participation in national technology development projects, support for the private sector to pursue its own research and development efforts and dissemination of newly developed technology. All of these activities are carried out in a concerted and internationally coordinated manner. By facilitating the practical application and commercialization of advanced new technology, NEDO endeavors to ensure a stable and efficient supply of energy under fluctuating domestic and international socio-economic conditions and to assist in the development of Japan's economy and industry. It does so by integrating the combined efforts of industry, academia and government.

In House R&D by Private Companies Abroad

The scale of investment by private companies outside is huge in some cases. Arcellor Mittal in 2011 spent about $300 million on R&D. They have over 1300 full time researchers. Similarly, "the Research, Development and Technology (RD&T) business of Corus combines top class innovation with cutting edge technology to deliver 'metals solutions' in a constantly changing world." They work closely with their customers to ensure that they get all the support they need to enable them to design new products and applications. They work in collaboration with universities and research institutes all over the world as well as with key customers in the automotive, transport, packaging and construction areas.[14]

[14] http://www.corusgroup.com

A.7: Private Sector Participation in R&D in India

In India, the major private steel producers like Tata Steel, JSPL, Essar etc have their in-house research facilities. They collaborate with universities and research institutions also. For example, product validation trials were carried out by Tata Steel for sponge chrome, a new product developed through R&D for production of ferrochrome, using Electric Arc Furnace facility at NML, Jamshedpur. As told by many stakeholders, mostly private companies focus on plant related issues and support researches which are useful to them comparatively in shorter term and the research is most of times incremental in nature. There is little evidence to show that the private companies invest significantly on basic research, which may have long gestation period.

At the same time, the private producers, especially Tata Steel collaborated in some R&D projects. Under the scheme also they collaborated. In one project, sanctioned under the scheme, Tata Steel and Essar were also involved initially. However, they withdrew from the project. While, the study team could not meet the representatives of these two companies, two issues came to notice-

(i) Ownership of intellectual property rights; and

(ii) Financial stake in the project.

Tata Steel requested for the ownership of physical and intellectual assets created under the project on the ground that the technology has been developed by them. There was a view within the Ministry also that the IPR issue may be agreed upon by the Ministry and ownership of intellectual ownership may remain vested in the developer of the technology. However, it was suggested that Tata Steel should be asked to allow 50% concession on market price of the technology in case government/PSUs wanted to procure/purchase it. DSIR also gave the opinion on the issue. They said that "the firm and the collaborating agency will own the IPR (as per the agreement they enter into). They will also indemnify the Government against any possible infringement of IPR. However, the company will be required to pay lump sum royalties in 5 annual installments amounting to 1.3 times the amount received, after start of commercial sale / commercial production of the product developed with the government support". DST also has similar position, wherein the IPR generated in a project remains with the agency developing it. However, they have to share the royalty / income in proportion to the share of the funding of the project. These are important issues and resolving them may lead to future collaborations in R&D. The ministerial position was also somewhat similar to what has been found in the modalities of Technology Roadmap Programme of USA. The whole issue, it seems, cropped up due to the fact, the conditionality was not determined before the implementation of the scheme. In fact, ***DSIR and DST guidelines could have been seen before designing the scheme and incorporated accordingly, which can now be done by the Ministry in designing its contract for award of research projects.***

The other issue which came to the notice of the study team related to the financial contribution to be made by the commercial organizations like SAIL or Tata Steel or any other. It limited government funding of up to 50% of the capital cost for commercial organizations. As mentioned earlier, in US the industrial participants provided cost-sharing support comprising of cash to the tune of 9.21% and 20.53% in the form of technical services, use of plant facilities and support personnel. ***The ministry may review its position on the limit of 50% contribution to the capital cost, especially in view of longer gestation periods in significant R&D projects, otherwise it may deter other commercial organizations from participating in the scheme, especially the smaller players. Moreover, the contribution in terms of technical services, use of plant facilities and support personnel should be factored into the contributions to be made by the commercial organizations.***

Again, we need to examine in the context of India, as to what extent, the private sector would participate in the R&D. As mentioned earlier, there are many small companies which have come up specially after the liberalization started in the 1990s. The big firms have their in house R&D, but the smaller players have limited capacities. If we see the phase in which the steel industry is at present, there is squeeze on the margins due to lower demand in the market. Even, bigger players have reduced their production. Contribution to R&D, in such a situation, becomes difficult for the industry. Moreover, R&D has a longer time frame. Even if we accept the fact that the downturns are because of cyclical nature of the industry, the smaller players may face problem in committing to R&D projects on a continuous basis. ***The manner of engagement of smaller players may be determined in consultation with them. Some experts suggested that these companies may contribute to the general pool of the scheme and be assured of royalties from the commercialization of the projects funded under the scheme and also royalty free***

use for themselves. They would also be eligible for tax concessions as per the government policy.

It is equally important to explore additional funds for R&D over and above what is already available. In this regard ***CSR (Corporate Social Responsibility) Funds have immense potential to provide additional liquidity for R&D activities***. There are studies which indicate that R&D may be considered part of CSR, provided it is for societal benefits (Annexure 1a, 1b and 1c). Department of Public Enterprise has also given an indicative list, which includes 'pollution control', environment friendly technologies' and 'activities related to the preservation of the environment/ecology and to sustainable development'. These are thrust areas under the scheme. If required, it may be further clarified either with the Ministry of Corporate Affairs or Ministry of Law.

PART B: BRIEF NOTES ON THE PROJECTS SANCTIONED UNDER THE SCHEME

B.1: Improvement in Sinter Productivity

Project Title	: Beneficiation and Agglomeration Technologies for Rational Utilization of Low Grade Iron Ores and Fines
Project Cost	: Rs. 12.56 Crore
Project Duration	: 36 months
Starting Date	: April 2010
Completion Date	: March 2013
Current Status of Project	: Project is likely to be completed by December 2013
Expenditure Incurred	: Rs. 7.81 Crore
Project Leader	: NML, Jamshedpur
Associates	: RDCIS, Ranchi, IMMT, Bhubaneswar and IIT, Kanpur
Principal Coordinator	: Dr. Ratnakar Singh, Scientist F

Project Objective:

Develop indigenous technology for effective utilization of low Indian iron ores, fines and slimes and meeting the demand of quality iron ore bearing raw materials.

Project Basic:

Now the reserves of high grade iron ore lumps are depleting and there is huge accumulation of low grade iron ore fines and slimes at mine heads and considering the huge demand in future, beneficiation and agglomeration technologies has to be developed.

Project Deliverable:

To deliver better quality of sinter from low grade iron ores and fines

Research focus and scope of the study

Present study is focusing on pilot scale trial on beneficiation, production of high grade iron ore concentrate (65% Fe), micro-pelletization and pilot scale production of micro-pellets, pilot scale sintering of micro-pellets with improved sinter productivity, techno-economic feasibility studies and industrial trials on sintering.

In case of iron ores, the major iron bearing minerals associated are hematite, magnetite, goethite and limonite with silica and alumina as gangue. Depending upon the origin and mineralogical and liberation characteristics of the ore, the beneficiation methods can vary from simple washing to complex concentration processes, For finer particles gravity, magnetic and froth floatation are applied.

In India high grade lumpy hematite ore and fines, which is used through sintering have been used for iron making but with fast depletion of high grade iron ore lumps it is necessary to utilize low grade iron ore and fines with suitable processing. Limited studies have been carried out by national laboratories on beneficiation of low grade ores and fines with success. But these pertain to lab scale studies and lack pilot scale trials to establish the technology for adoption by the industries. Further, utilization of fine grained beneficiated iron ore concentrate for iron making through blast furnace is impaired following conventional pelletization because of cost-intensive curing process.

Existing Technology

Beneficiation of Low Grade Iron Ores

The present technology of iron ore beneficiation comprises broadly on crushing ore to required size, scrubbing and/or wet screening, classification to separate slimes from fines. By washing the adhering clay matter is removed, but the Al_2O_3 content is not significantly lowered. This technology is suitable for high grade ores but there are limitations in treating low grade ores because of complex nature of elimination of alumina.

Studies on application of advanced separation process involving gravity, magnetic and floatation based techniques can lead to development of innovative processes for cost effective beneficiation of low grade ores. The process can be extended to lean grade iron ores such as Banded Hematite Jasper (BHJ), Banded Hematite Quartzite (BHQ) and Banded Magnetite Quartzite (BMQ). These ore generally contain high silica impurities (40-50%), while alumina content is low (1-2%) with liberation in the fine size below 75 micron.

Iron ore fines & slimes

Iron ore fines and slimes generation rate in India is about 60% of total ore production. Because of low off-take of fines as well as use of low percentage of sinter use in the blast furnace burden in early years, there is huge accumulation in the mine heads. Presently, high grade iron ore fines of -10 mm size are used in sintering machine, however -3 mm fraction has limited use in sintering and ultra fines are still unused. These are dumped at mine heads, used for landfill or exported to China with low realization.

From the stand point of view of conservation of iron ore resources as well as protection of environment, rational utilization of iron ore fines, overburden and slimes needs to be emphasized. With the increase in global demand of high grade iron ores and gradual shift on the use of lumps to agglomerate for iron making, there is enough scope to effectively utilize dumped fines, overburden and slimes.

Agglomeration of beneficiated iron ore

The possible option for utilization of beneficiated iron ore, available in the fine size could be agglomeration of the fines into pellets or briquettes. But the inadequate hot strength of regular briquettes precludes their use in blast furnace. The hot strength of pellets is poor; however a curing treatment at 1250-1300^{0}C imparts high strength to make pellets suitable for use in blast furnace. Other alternative routes for iron ore fines utilization like smelting reduction is still under development except COREX.

Sinter is the only low cost agglomerate which can be successfully used in the blast furnace. Therefore, for utilization of these fines, sintering may be appropriate route. If these ultra fines materials are pelletized, the bed permeability may be overcome. Therefore utilization of ultra fines iron ore can be done in blast furnace through micro-pelletization followed by sintering.

New/Improved Technology

The new technology is being developed in two phases:

Phase 1 will focus on the development of beneficiation and agglomeration technologies.

Phase II will focus on the industrial trial on sintering using micro pellets as the partial feed.

Status of work done in national/international Arena:

National

The sintering technology is widely prevalent in our country. Similar research work to improve the sinter productivity has been done at IMMT, Bhubaneswar and TATA Steel, Jamshedpur on characterization, beneficiation of raw materials and agglomeration of iron ore fines and plant wastes. Scrubbing, jigging, magnetic separation or floatation techniques were employed to enrich the Fe value present in the different low-grade samples.

International
Since the quality of iron ore in India is different from other countries, there is not much reference of similar work done except that concentrates resulting from beneficiation of low grade ores are of fine granulometry and used in the forms of pellets for iron making.

SWOT Analysis:

Strengths
Expertise and Capability- NML, Jamshedpur has developed excellent expertise in doing similar research work in the mineral processing department. It has well equipped laboratory. There has been positive response from the preliminary work done. The collaborator RDCIS, Ranchi, IMMT, Bhubaneswar and IIT, Kanpur have experience of conducting similar research work.

It would establish prospects for utilization of low grade iron ore resources and thereby increase the reserve base. Development of novel route for agglomeration of beneficiated fines/slimes involving micro-pelletization and sintering would be beneficial. There would be increase in waste utilization because of use of dumped low grade fines. It would lead to reduction in environmental impacts due to washing recycling of rejects from iron ore washing plant and mine waste dumps.

Weakness
Presence of coal adversely affects the strength of pellets(it is reduced to about 1/10th of the cold crushing strength of the pellets without coal). Fineness and clay content adversely affect the pelletization behavior of the ore.

Opportunity
Knowledge base on characteristics of low and lean grade iron ores, dumped fines and waste slimes will be increased. There will be employment opportunity on establishment of beneficiation/agglomeration plants. Training and development of human resources will also increase. Considering the impact on environment of the present steel industries the new technology will be helpful in reducing green gas emissions.

Threat
The only threat to this technology is growing presence of pellet industries in India and other alternate techniques of making iron and steel.

Enablers:

Availability of low and lean grade ore/fine/slimes and wastes in large scale in our country is most important enabling factor. Present industrial practice is not suitable for exploitation of low grade ore and conservation of resources. Conventional pelletization has high cost of induration. Sinter is low cost agglomerate. Growing concerns over pollution control has led to its inclusion in the thrust areas of R&D.

Disabler:

Absence of broad based research environment on the subject and data may be significant disabling factor.

Techno-Economic Assessment:

Since project is still in development phase, techno-economic assessment has not been carried out. A techno-economic feasibility study may be undertaken once the process is developed. The prime focus of the present research is to develop indigenous viable technology for effective utilization of low and lean grade Indian iron ores/fines/slimes and meeting the demand of quality iron bearing raw materials for iron and steel making with the prime objective of development of sintering technology utilizing fine grained concentrate as micro-pellet as the partial feed.

Since of cost of production of producing sinter is cheaper than sponge iron and pellets there will be huge reduction in overall cost of production of finished steel.

Conclusion:

Project initiatives are in line with the project objective. Regarding time lines, the project has been delayed by about 9 months. Monitoring of different project activities has been good but coordination with partner institutes may further improve.

Blast furnace continues to be the dominating route for production of pig iron. The requirement of economical operation of blast furnace operation w.r.to iron ores and agglomerates differ from furnace to furnace in different parts of the world. As per the price-quality consideration the iron ore should contain maximum iron with minimum gangue. It is desirable to burden a furnace to attain minimum slag volume with optimum elimination of sulfur and alkalis in the slag.

India has a good quality iron ore reserve of about 14 billion tons. During mining the generation of fines and slimes are 35% and 15% respectively. Present production of iron ore in India is about 220 million tons. Considering the GDP growth rate of 8% the projected requirement of iron ore by 2019-20 would be 500 million tons. The biggest challenge before Indian steel industry would be the input raw material security mainly the iron ore. Lump availability is decreasing and with mechanized mining generation of low grade fines which cannot be used for sintering is increasing, as a result more than 100 million tons of dumped fines and slimes (low grade iron ore) are accumulated at the various mine heads in the country. We may soon be left with low grade ore below 55% Fe. Considering the overall scenario Indian Bureau of Mines (IBM) has brought down the cut-off level of Fe to 45%.

Considering the increasing demand and conservation of iron ore reserves, it is imperative to develop beneficiation and agglomeration technologies towards exploitation and rational utilization low grade iron ore fines and slimes. For the finely disseminated low grade ores the techniques like gravity, magnetic and froth floatation are being dominantly used, as practiced in other countries. So far, most of the work has been on lab scale and lacks pilot scale to establish the technology for adoption by the industries. Further emphasis is to be given on developing cost effective agglomeration to find amicable solution to the problem. Presently, high grade iron ore fines of -10mm are conventionally used in sintering machine but -3 mm has limited use thus there is enough scope to effectively utilize dumped fines, over burden and slimes. For pellets curing process is cost intensive, other alternative routes for iron ore fines utilization like smelting reduction is still under development except COREX, thus sinter is the only option which can be successfully used in the blast furnace. There is a need to increase the use of ultra-fine iron ore concentrate in blast furnace through micro-pelletization. By using micro pellets sinter productivity also can be used to a great extent. Therefore, this project is highly relevant and needs to be supported further.

B.2: Alternate Complementary Route of Direct Steel Making with reference to Indian Raw Materials

Project Title	: Alternate complementary route of Iron/Steel making with reference to Indian raw materials
Project Cost	: Rs. 8.58 Crore
Project Duration	: 36 months
Starting Date	: April 2010
Completion Date	: March 2013
Current status of Project	: Likely to be completed by December 2013
Expenditure Incurred	: Rs.5.04 Crore
Project Leader	: NML, Jamshedpur
Associates	: IMMT- Bhubaneswar, AMPRI- Bhopal, CIMFR- Dhanbad, RDCIS- Ranchi
Principal Coordinator	: Dr. Ratnakar Singh, Scientist F

Project Objective

The prime objective of the research programme is to develop indigenous viable technology for developing an effective alternative steel making technology for small and medium sectors utilizing beneficiated iron ore and coal fines.

Project Basic

The most common route for large scale steel making is Blast Furnace (BF)/ Basic oxygen furnace (BOF) route. The main reasons for this are efficiency, scale of operation and cost competitiveness. The second route is Direct Reduction of Iron (DRI) but this route suffers from the basic constraints of high quality iron ore. In India during mining there is huge generation of iron ore fines and slimes which cannot be directly used for agglomeration. Hence it is necessary to upgrade iron ore fines to 65% Fe and find out alternate route for iron making using the concentrate of iron ore and coal fines.

Project Deliverable: The project deliverable is the development of process for making mini-pelletized Ferro-carbon. (Additionally carbonized and reduced iron oxides)

Project linkage: There is no linkage at present with any steel producer.

Existing Technology:

As mentioned earlier the most competitive, common and easy route for iron and steel making on a large scale is Blast Furnace/ COREX-BOF. In this process first liquid iron is made and then this liquid iron along with some other alloys is oxidized to make different grades of steel. The alternate route of iron and steel making is coal based DRI. This route suffers from the basic constraints of limited availability of high quality iron ore lump, meeting the requisite physical and chemical properties and high ash Indian non-coking coal.

According to Geological Survey of India the total reserves of good quality iron ore and coking coal is limited and would last hardly for 25-30 years. Small scale producers do not have access to good quality iron ore and coking coal and they always depend upon iron ore fines and coal.

New and Improved Technology:

The new and improved technology proposes to beneficiate low grade iron ore to around 65%Fe and coal up to 12% ash level. Micro-pelletization of iron ore concentrates will be done with and without coal. Optimization of Ferro-carbon will be done in coke oven to achieve 90% metallization. Optimization of smelting of Ferro-carbon for steel making will be done in Submerged Arc Furnace (SAF), Electric Arc Furnace (EAF) and Electric Oxygen Furnace (EOF).

The proposed technology is an alternate route for iron making using iron ore fines and low grade coal. The product can be used in a conventional SAF/EAF/EOF along with coal based DRI produced from deep beneficiated Indian iron ore fines based pellets.

The most innovative feature of the new technology may be utilization of low grade ore, slimes and waste material, use of high grade iron ore micro-fines not suitable for sintering, alternative route of iron/steel making and meeting the environmental norms.

Status of work done in National/International Arena:

National

This is a new concept in iron and steel making. In India some preliminary work has been done at NML-Jamshedpur and JSW-Vijaynagar. Some limited success has been reported from both these places.

International Status:

Not much has been done in international arena in this regard as most of the major steel producers import raw materials of good quality.

SWOT Analysis:

Strength

The major strength of this research project is increase in waste utilization because of use of dumped low grade iron ore fines. It would lead to utilization of low grade micro- fines, slimes and wastes, growing concerns over pollution control, stress on green manufacturing of steel and improving energy efficiency There will be less CO_2 emission because of utilization of coke oven gas.

Weakness

Since this is new concept broad based data is not available. Because of multi location facilities, sample selection and collection of data from various locations are other weaknesses of this project. Some difficulties are faced in optimization of blend ratio and operating parameters.

Opportunity

BF/COREX-BOF route require good quality of iron ore and huge investment and both these are out of reach for low and medium players in the steel industry. Hence in the back drop of above constraint there is ample opportunity for small and medium producers. Considering the impact on environment of the present steel industries the new technology will be helpful in less GHG emissions and green manufacturing of steel.

Threat

There is growing presence of pellet industries in India and uncertainty of operation of Jharia coalfield from where coal is to be sourced. There is also no direct linkage with any steel plant hence conversion of bench scale and pilot scale trial for industrial use will be difficult.

Enablers:

NML, Jamshedpur a national repute research institute has developed excellent expertise in doing similar research work in the mineral processing. It has all types of modern facilities and well equipped laboratory. The collaborators like RDCIS, Ranchi, IMMT, Bhubaneswar, CIMFR, Dhanbad, AMPRI, Bhopal also has expertise in conducting similar kind of research work.

Disablers:

Pilot coke oven at CIMFR-Dhanbad has not yet fully stabilized.

Techno-Economic Assessment:

The project is still in development phase; hence techno-economic assessment has not been carried out. Since the reduction of iron ore is proposed to be achieved in coke oven and the coke oven gas will also be applied for heating/power generation. There may be reduction in cost of production and CO_2 emissions to atmosphere will also reduce.

Conclusion

Project initiatives are in line with the project objectives. Regarding adherence to the time line, the project is running behind schedule by about 9 months. Coordination and monitoring mechanism with partner institutes is good.

BF/BOF accounts for 70% steel making in the country. The basic constraints in Blast Furnace iron making practice in India is linked to two prime input material that is the quality of iron ore and indigenous coal. India has rich hematite iron ore reserve but inherent alumina to silica ratio in Indian hematite ore results in complicated Blast Furnace slag chemistry. More than 15% alumina in the slag leads to various complication in the smooth operation of Blast Furnace.

Indian coking coal is of medium quality and we have been beneficiating coking coal to ash level of around 17%. Deep beneficiation of Indian coking coal with reasonable yield does not seem to be economically feasible with reference to the prevailing price of high quality prime coking coal.

The alternate route of coal based DRI production also suffers from the basic constraints of limited availability of high quality iron ore lump and high ash content of Indian non coking coal. Due to the above reasons, it is essential to develop a complementary route more focused to specific Indian raw materials constraints.

As reported by NML, the activities at AMPRI-Bhopal have been closed and the balance fund has been transferred to NML-Jamshedpur.

B.3: Production of Low Phosphorus Steel

Project Title	: Production of Low Phosphorus Steel Using DRI through Induction Furnace Route
Project Cost	: Rs. 2.37 Crore
Project Duration	: 24 months
Starting Date	: April 2010
Completion Date	: March 2013
Status of Project	: Completed
Expenditure Incurred	: 2.37 Crore
Project Leader	: NML, Jamshedpur
Associates	: NISST, Mandy Govindgarh
Principal Coordinator	: Dr. R. K. Minz, Scientist E

Project Objective:

The basic objective is the development of a suitable technology for effective and efficient dephosphorisation of liquid metal in induction furnace.

Project Basic:

The average phosphorus content in steel produced through DRI and Induction Furnace route is in the range of 0.06 to 0.1%. The required phosphorus content in any structural steel should be below 0.03%. Being insulator, it is difficult to melt slag and maintain its fluidity through induction heating. In this project it has been planned to remove phosphorus through, development/selection of appropriate flux, suitable process modification and improvement in furnace design, including furnace lining.

Project Deliverable:

The main deliverable is liquid steel with low phosphorus content.

Project Linkage: At present there is no linkage with any induction furnace steel producer in the first phase. The user industry for execution of the second phase will be identified at an appropriate time with assistance from National Institute of Secondary Steel Technology (NISST), Mandy Govindgarh, Punjab, in the second phase.

Existing Technology:

About 20 million tons of steel is produced through DRI in induction furnace and casted in the form of ingots, blooms, billets for downward production of long products like bars and rods, structural steel and railway materials. The induction furnace route has limitations for refining of liquid metal and treatment with flux to produce low phosphorus and low sulfur steel. Against a desired phosphorus level in structural steel of 0.03%, the achievement in induction furnace using DRI is 0.06-0.1%. Thus steel produced in induction furnace using DRI is not suitable for high end structural steel.

New Technology:

In view of the technological gap NML, Jamshedpur has taken following steps in developing the new technology- develop appropriate flux, charge mix suitable for dephosphorisation and compatibility with furnace lining. Change engineering lining to suit the process, and modify induction furnace design for oxygen purging to enhance the reaction kinetics.

Few preliminary experiments have been carried out for dephosphorisation of steel using DRI in induction furnace with suitable flux composition and the result is encouraging. The method of dephosphorisation in the process of steel production in an induction furnace comprises of, controlling the temperature of molten steel below 1450°C performing dephosphorisation treatment on liquid steel by using dephosphorising agent, (lime ferric oxide-boron anhydrous), and controlling the phosphorus content in the liquid steel. After finishing the dephosphorisation, deslagging, then rapidly raising the temperature of the liquid steel to 1500°C-1600°C and performing pre-deoxidation and then adding dephosphorisation agent consisting of lime-calcium, carbide aluminum ash are done.

Status of work done in national/international Arena:

National

At the national level not much work has been done on dephosphorisation for the production of liquid steel through induction furnaces route in India.

International

Due to the reducing quality of iron ore hot metal impurities have increased. Lot of research has been done on molten iron dephosphorisation and slag system in other countries. In laboratory 10 kg-level induction furnace with composition of various slag compositions was carried out in Chongging University, China. Similar research work on dephosporisation in liquid steel making through induction finance has been done and expressed in the paper presented by University of Jangsu, China.

SWOT Analysis:

Strength:

In dephosporisation of liquid steel through induction furnace route requirement of electricity is low, yield is high, requirement of electrode is also low, and above all the chances of pollution is also lowest.

Preliminary experiments have been carried for dephosphorisation of steel using DRI in induction furnace with suitable flux composition has shown encouraging result.

Weakness

The important drawback or weakness of the project is non-availability of broad based data. Secondly as has been mentioned above, there is no direct linkage with any steel industry for taking it up to industrial scale. User industries for execution of the second phase need to be identified with the assistance of NISST, Mandy Govindgarh. The use of dephosphorisation of steel using DRI in induction furnace to commercial use will be difficult and time taking without identifying induction furnace steel producers.

Opportunity

With the growth in infrastructural sector the demand for long product category of steel has increased in recent years. About 50% steel produced in India belongs to long product category and out of this half of the quantity is produced through induction furnace and DRI route. If phosphorus level is brought down to <0.03% there is huge opportunity to increase the market share in long products. Iron ore self-sufficiency rate is decreasing year by year; this gives an opportunity for more and more emphasis on electric routes including induction furnaces. Due to growth in demand of structural steel, low production cost and low CO_2 emissions, low metal loss and dust generation, the success of this project would be beneficial for the industry.

Enablers:

NML, Jamshedpur has very rich research and development experience in the area of iron making and steel making. NML has well equipped laboratory and various similar sponsored projects has been undertaken and executed in the past. For the last ten years ferrous group has been working on dephosphorisation.

Disablers:

There is growing demand for better quality structural steel, limiting the presence of phosphorus in the liquid steel produced through induction furnace. However, lining gets eroded severely due to slag and low lining thickness. It is difficult to handle high melting point high viscosity slag and double de-slagging practice.

Techno-Economic Assessment:

Since the technology is still in stabilization phase. It is difficult to do techno economic assessment of the technology. This can be done only when it is put to commercial use at a lower scale.

CONCLUSION:

The project initiatives were in line of the project objectives. The project has been completed. Coordination with the partner institute was good.

About 1800 induction furnace units are operating in India producing about 22 million tons of steel. Percentage contribution of induction furnace is about 31%. Most of the steel produced through induction furnace route is used in long steel product that is mainly structural steel. There are various limitations of induction furnace for refining of steel viz. lack of slag-metal mixing, formation of hard crust at the top of the furnace, low lining thickness etc.

Several experiments have been conducted in the past in induction furnace with different flux combinations to test feasibility of dephosphorisation. Desired level of phosphorus can be achieved with above flux combination. Phosphorus content in the treated steel has to conform to the specifications of structural steel. The final phosphorus content in the liquid steel is reduced to below 10 ppm by deeply dephosphorising the liquid steel in an induction furnace using appropriately selected slag.

Lowering the phosphorus content in steel is a critical requirement for steels used in deep drawn application as all applications require uniform deformability. Phosphorus is also known to make the steel prone to embrittlement during heat treatment and cause degradation of electrical properties. To increase the market share of steel produced through induction furnace further experiments need to be conducted on development/selection of appropriate flux, suitable process modifications and improvement in induction furnace design.

With the growing investment in infrastructure sector in 12^{th} five year plan in India the demand for structural steel is going to increase and if the production through induction furnace route is increased, because of the cost advantage, then induction furnace industries will be in an advantageous position.

First phase of the project has already been completed. The second phase will be undertaken later only after a suitable furnace of desired size is chosen to carry out the balance work.

B.4: Reduction of Iron Ores/Fines by Hydrogen Plasma

Project Title : Smelting Reduction of Iron Ore

Project Cost : Rs. 9.90 Crore

Project Duration : 36 months

Starting Date : April 2010

Completion Date : March 2013

Current status of Project : Project is likely to be completed by March 2014 (Project has been extended by one year)

Expenditure Incurred : 7.67 Crore

Project Leader : IMMT, Bhubaneswar

Associates : None

Principal Coordinator : Dr. B. Bhoi, Scientist F

Project Objective:

1. To produce iron by smelting reduction of iron ore / fines using hydrogen plasma, thereby totally eliminating CO_2 emission.
2. To demonstrate the above environment friendly iron making process in bench scale and develop flow sheet.

Project Basic:

Conventional iron making processes with multiple steps, either by Blast Furnace (BF) or Direct Reduction of Iron (DRI) route, have high CO_2 emission and energy consumption. The single stage reduction will result in considerable saving in energy consumption and use of hydrogen will eliminate CO_2 emission and there would be pure quality iron product without carbon and sulfur.

Project Deliverable:

Project deliverable is high quality iron with lower energy consumption and zero CO_2 emission.

Project linkage: RINL, Visakhapatnam, which has agreed to conduct pilot scale study.

Existing Technology: Presently pig iron is being produced by

1 Conventional Blast Furnace route; and

2 DRI route, gas based or coal based.

BF process of iron making involves carbothermic reduction from iron oxides Hematite Fe_2O_3 or Magnetite Fe_3O_4. There are more than 50 Blast Furnaces in operation varying from 550-3200 M^3. Recently 3800 M^3 BF has been commissioned at TATA Steel, Jamshedpur. One 4060 M^3 BF at IISCO Burnpur of SAIL is ready for commissioning. Two similar BF are being built at Rourkela and Bhilai steel plants of SAIL.

The CO and CO_2 generation in commercial blast furnaces are higher. In addition to this there is further generation of these gases in the coke oven plant while preparing coke for the blast furnace. DRI (Sponge Iron) is the solid metallic iron obtained upon Direct Reduction of high grade iron ore. There are two established process routes- one gas based, using natural and coal based gases, other using non coking coal. There are other two gas based DRI processes in the world i.e. MIDREX and HYL-III.

Sponge iron and pellets are agglomerated from iron which is used as direct feed material for making steel in Electric Arc Furnace. Alternative Iron making processes are COREX, FINEX, HIsmelt and IT mk3. COREX process of making steel is operational in JSW steel plant at Vijaynagar and ESSAR steel plant at Hazira. FINEX two Million Tons module is working at POSCO Pohang, South Korea. POSCO is trying to have collaboration with Indian steel producers but so far, they have not been successful. First 0.8 MTPA HIsmelt plant was setup at Kwinana, Australia, which is under stabilization. The first commercial plant of ITmk3 of 0.5 MTPA is in operation since 2005 at Kobe steel, Japan. An MOU has been signed between SAIL and Kobe Steel for this technology.

Hydrogen Plasma Smelting Reduction: An option for Steel making in the future

All iron based materials are originally produced from iron ore. The steel industry is a major source of global CO_2 emission. Large reduction in the green house gases is the challenge to develop new processes, like Hydrogen Plasma Smelting Reduction (HSPR). Because carbon is the main energy carrier and the reducing agent used in the iron making, the steel industry is considered to be one of those industries responsible for global warming. Currently 95% of steel are made from iron ore via the blast furnace/ basic oxygen furnace (BF-BOF) that is two step routes and 5% via direct reduction and electric arc furnace (DRI-EAF) three step routes.

A third route for producing Iron in future should be one step that is HPSR. The proposed new technology herein involves extraction of iron, free from carbon using hydrogen as reducing agent. Hydrogen plasma which serves both as the heating source as well as reductant is employed to produce liquid iron through smelting process. Plasma reaction of hydrogen ion and iron oxide is reported to be lower than that of molecular hydrogen and iron oxide. Thus, kinetics of reduction will be faster in hydrogen plasma. There is no CO or CO_2 emission. Thus the process is chimneyless smelting.

Project Development at IMMT Bhubaneswar:

The project was initially started with the development of a plasma smelting process carried out in a micro oven plasma reactor at 2gm. scale. After a gap of about 3 months the experiment was carried on 15 gm. scale. Later on experiment was done on 40 gm. scale. Micro oven plasma reactor was later modified in house and a hydrogen plasma smelter reactor was fabricated and experiment was done on 50 gm. scale.

In 2012, experiment was carried on the scale of 200 mg. and 400 mg. scale. From Jan 2013-March 2013 experiment was carried out on a scale of 600mg. Plasma torches and tungsten electrodes based arcs were employed using hydrogen as plasma forming gas. Entire process was carried out with adequate safety and control system in view of the hydrogen handling. Scale of operation has been further modified in two stages by suitably modifying the plasma reactor and plasma torches. Modification has also been done in feeding system of iron.

For the purpose of commercialization of the technology and also suggested by the PRC in its third meeting, the project team plans to reach a scale of 1000 gm in next six months of 2013 through improved designs of equipment. Based on the progress so far and with the difficulty being faced in developing the equipment indigenously, the project completion may take some more time. However, as this is a path breaking research, the necessary support and extension of time should be given.

Similar work done in National and International Arena

National

At the national level in India, iron production through thermal plasma using hydrogen has not been focused significantly. No institution has used or initiated the work on HPSR before the scheme was started by the Ministry of Steel.

At present, Plasma centre of IMMT, Bhubaneswar is working for the last 25 years to produce various types of irons viz. pig iron, cast iron, SG iron and Ferro alloys employing argon plasma. The institute holds several patents in plasma smelting of iron ores.

International

A detailed analysis of the reduction of iron ore with hydrogen in a direct current plasma jet was carried out by Gilles and Clump (UK) in 1970 but it could not proceed further.

Reduction of molten metal iron oxide and FeO bearing slag was reported by Kamiya Metals (Japan) in 1984.

Plasma arc melting to produce high-purity semiconductor grade Fe was done by Uchikoshi, Japan in 2004.

H Hiebler and JF Plaul in 2004, based on laboratory experiment, led to a large scale industrial plant concept which suggested that hydrogen plasma smelting reduction can be a good option for steel making with higher product quality and flexibility.

All these could remain up to presentation and conceptual stage and could not be taken to pilot scale that is why sufficient progress has not been made for taking it up to industrial use.

HPSR Technology Assessment:

The concept behind an HPSR plant for continuous production of 75 ton liquid steel per hour equating to 1.2 million tons per year on laboratory scale has been described in various literatures. The preheated fine iron ore is transported continuously into the HPSR reactor with small amount of lime or dolomite to achieve suitable slag viscosity. A continuous 82 MW electricity supply and Hydrogen gas supply of 100,000 Nm3/hr are required. Hot exhaust gas from the reactor is mixed with cold gas and additional hydrogen and argon are added to make up the required concentration before the gas is recycled back into the process. Slag (max. 6 ton/ hour) is forced to the wall of the reactor and is tapped off in a controlled manner. The degree of reaction can be controlled by the holding time. Smelting temperature is over 3000^0C. The mass and energy balance, the way in which the reaction proceeds and the metallurgical aspects of the HPSR can be adequately described and evaluated based on the laboratory tests.

As on today use of hydrogen plasma in iron and steel industry, still is in infancy stage and mostly lab based concepts are being reported.

The following problems have been faced in lab and pilot plant research both in India and abroad:

- Continuous pre-heating of the ore fines and transport into the HPSR reactor.
- Design of the reactor and control of high- energy concentration.
- Control of the necessary large volume of gas.
- Refractory lining and cooling of the reactor.

A full scale version of this concept can only be realized following several years of research work on a pilot plant.

SWOT Analysis:

Strength

Major strengths of the HPSR technology in Iron making can be, the reduction in specific energy consumption as compared to BF/DRI route. Electric power consumption in HPSR would be less in the plasma technology. There would be reduction in specific raw material consumption both iron ore and flux, since plasma bath temperature is high. There would be no dependence on coke or coal. Coke is needed for reduction in Blast Furnace and coal is needed for reduction in DRI, whereas, in HPSR, reduction takes place with hydrogen plasma. There would be less concentration of impurities like Phosphorus, Sulfur, Aluminum, Silicon etc. Because of higher melting point some amount of these impurities gets burnt, thus reducing the contents in the pure iron produced by HPSR. Coke ovens, Blast Furnace, Sinter plant are not needed as there will be no need of coke and sinter. Iron ore fines are available in plenty at cheaper price; and there would be better environment and pollution control and less percentage of CO and CO_2 in the gas blown in air.

Weakness:

Lack of existing know-how, though hydrogen smelting technology is available in India but it is being tried for the first time in steel making, hence not much know-how is available indigenously for iron ore smelting. Equipment needed is developed indigenously and availability of lab equipment from Indian sources is difficult, whatever has been developed it has been done in house. Plasma torches life is less and till date no concrete solution has been found. Defect rectification of problems faced during testing takes time. Continuous pre-heating of the iron ore fines and transport into the HPSR reactor and control of large volume of the gas are also posing problems. Work has still not reached 1000 kg scale, so predicting the future activities is uncertain.

Opportunity:

There will be no dependence on either coking or non coking coal for iron making future. Since basic feed material is iron ore fines hence iron ore or coal beneficiation is not needed. Green iron manufacturing, as the most dissipation of two polluting elements CO and CO_2 in the atmosphere will be very less. Generated waste is water which has got huge potential for reuse. The demand for carbon free iron is well established in our country hence there will be a very wide application area. With the present scenario of depleting iron ore lump availability and more checks by environmental authorities and restrictions imposed by honorable Supreme Court on illegal mining, particularly in Goa and Karnataka, more and more emphasis is being laid on DRI and pelletization. CO_2 emissions would be very low and SO_2 and NO_x emissions also may be reduced to minimum. Considering all the facts above, HPSR will be a technology of the future iron making.

Threat:

Use of hydrogen gas is commercially not viable at present. The cost of production of hydrogen gas for the amount needed seems to be a costly option. Moreover, since the process is still at laboratory stage and full scale version of this concept can only be realized following several years of research on the pilot plant. Reaching to a stage where it can be put to industrial use can take longer time. In the mean while there may be enough work in coal and iron ore beneficiation that it may be commercially difficult to compete with conventional BF/DRI route. For future development of reactor module they have to be dependent on imported equipment know-how.

Enablers:

Lower investment cost- cost of setting an integrated steel plant or other steel making technology is higher as compared to HPSR. One step innovative technology would completely eliminating primary zone of Coke Ovens, Sinter Plant and Blast Furnace. Throughput time and flexibility- in an integrated steel plant it takes about 40 hrs from raw materials to finished product, the estimated throughput time in HPSR may be around 3 hours. Expertise and facilities available at IMMT are comparable to the international standard. The project team members are very optimistic about the success of the project. Organizational leadership provided by the present Director has motivated the entire workforce.

Disablers:
Disabling factors include higher and fluctuating electrical energy cost and continuous supply of high voltage electrical energy at a reasonable cost. Longer lead time and investment risks. Experience has shown ore reduction technology requires 100-200 million Euro investment and a development period of 10 years between conception and first industrial plant.

One of the biggest challenges for the above process is the commercial production of Hydrogen gas at an economical viable rate. With the technology being used to produce hydrogen cost of production is higher as compared to other reducing element.

Techno-Economic Assessment;
The amount of energy required to produce per ton of steel has been reduced by 50% in last 30 years but considering the global completion and pressure on net sales realization (NSR) still there is huge scope for cost reduction. When we compare the cost of production of per ton HR coil and simulated cost of HPSR, there may be scope for cost reduction of about 21% as compared to conventional BF-BOF route. Considering an increase of about 8% on account of electrical energy and hydrogen gas, there is a scope of 13% cost reduction. The project is still in pilot stage, hence exact techno economics can' not be assessed now.[15]

Conclusion:
The project initiatives are in line with the project objectives. The project has been delayed by one year due to exogenous factors.

A new steel making technology based on iron ore with hydrogen as reducing agent and electric energy has been shown. The basic scientific work and technological solutions have been carried out. The results of the experiments have led to the development of a concept

[15]Hiebler, H. and Plaul, J.F., 2004, *'Hydrogen Plasma Smelting Reduction: An Option for Steel Making in Future'* METALURGIJA, 43, 3, p. 155-162

for HSPR plant on industrial scale with the capacity to continuously produce an iron melt, free of carbon and sulfur, in a single stage using iron ore fines.

A technology assessment has shown that HSPR, if it were available today, could result in steel production up-to 20% cheaper than by conventional steel making routes, and with higher product quality, flexibility and in an absolute environmental friendly way.[16]

As the demand for steel increases, CO_2 emissions will continue to rise. In the long run the only solution is to use hydrogen instead of carbon. Project coordinator informed that they are looking for a suitable tie up with Austria for future activities. Hydrogen Plasma Smelting Reduction (HPSR) has been under research at the Department of Ferrous Metallurgy at the University of Leoben, Austria for last 15 years. It is recommended that IMMT should have collaboration with Leoben University, who has been doing similar work in the field HPSR technology.

There has been saving in the procurement cost of capital equipment. This could be utilized for development of modification in the design of torches, which is giving frequent problem. The process can be described as a futuristic process due to lack of mature experimental results (Pilot scale), relatively high consumption of electricity and high cost of hydrogen. In some of the tests, methane gas was mixed with argon to evaluate methane reduction. It has been found that methane reduction is 4 times faster than hydrogen.

Since this is an innovative project and in spite of the R&D risk being highest in HPSR, compared to the conventional route, all support needs to be given for pushing this project on a faster mode, which would lead to the green production of iron in single stage.

[16] *Ibid*, p.155-162

B.5: Beneficiation of Iron Ore Slime

Project Title	: Beneficiation of Iron ore slimes from Barsua and other Mines in India
Project Cost	: Rs. 27.69 Crore
Project Duration	: 36 months
Starting Date	: January 2011
Completion Date	: December 2013
Current Status of Project	: Likely completion by December 2014 (Project has been given one year extension)
Expenditure Incurred	: Rs. 1.48 Crore
Project Leader	: RDCIS, Ranchi
Associates	: IMMT- Bhubaneswar and NML- Jamshedpur
Principal Coordinator	: Dr. S. K. Pan, DGM, RDCIS

Project Objective:

To recover iron ore fines concentrate with ~64% Fe with Sio_2+ Al_2O_3<5% from slime/process rejects having 55-57 Fe at minimum 50% yield.

Setting up a slime beneficiation plant of 50 ton/hour capacity for treating online process rejects.

Project Basic:

The quality of iron ore fines at Barsua mines is much inferior compared to other mines of SAIL, because of presence of high alumina in mores. Also Gibbsite & Goethite minerals are interlocked in the hematite matrix. Even after processing these "difficult to upgrade" ores through various equipment, the quality of product fines still contains very high % of gangue. As a result 28% slime of R.O.M. is generated and gets lost to tailing dam. The project basic is to recover iron values to Fe ~64% and bring gangue to <5% at a rate of 50 ton per hour.

Project Deliverable: Iron ore with Fe content of ~64% and Sio_2+ Al_2O_3<5%

Project linkage: Barsua mines of Raw Materials Division of SAIL

Project Activities:

The activities undertaken by various institutes are:

I. Bench scale beneficiation studies for development of process route at IMMT, NML and RDCIS.
II. Pilot scale studies on the frozen flow-sheet at NML-Jamshedpur.

III. Installation and commissioning of demonstration plant at Barsua mine.

IV. Systematic trial to process slime online.

V. Process optimization.

Existing Technology:

Barsua mines are gifted with rich quality ore but at the same time it is highly aluminous in nature. It is equipped with Remer jig and Spiral classifier for fine ore treatment. Even with these facilities Barsua mines produce poor quality slimes, due to presence of hydroxide form of alumina, which is very difficult to separate from the ore body. Various experiments carried out on different samples show that by adjusting operating parameters of mineral processing units iron values present in slimes can be recovered. The piece meal work carried out so far has not helped till date to develop a suitable technology for the utilization of vast resources of iron ore slimes accumulated over in iron ore tailing ponds.

New Technology:

A new promising technology "magnetic carrier technology" which offers some advantage over other conventional mineral separation techniques can be applied thereby reducing the cost of separation. Suitable grinding method of the coarser fraction of slime (to liberate at least to 60% level) would be developed followed by effective separation of those gangue mineral particles. The concept of Point of Zero Charge (PZC) effect along with use of special type of organic Polymer as a surface active agent would be tried to liberate and separate the gangue minerals from the iron minerals in slimes.

The process flow sheet for beneficiation of slime will be developed in the laboratory scale. Based on the results of laboratory / bench scale studies process will be synthesized and validated through pilot scale trials. The proven process flow sheet will be implemented by way of setting up of a demonstration plant of 50 ton/ hour product capacity at the mines site.

In view of the huge losses of iron values in the form of slimes, it proposes to develop new technology based on the detailed characterization of the slimes and laboratory studies on separation of minerals by advanced gravity/floatation and magnetic separation/selective flocculation techniques.

Status of work done in national/international arena:

National

In India, iron ore beneficiation work has been done by various national level iron ore producing mines. The mineral processing departments of IMMT, Bhubaneswar and NML, Jamshedpur are among the lead agencies in doing research work in iron ore fines and slime beneficiations. Almost all the national level institutes in India dealing with ore processing have carried out test work at their respective laboratories. Essar Steel has also made beneficiation facilities at Bailadila mines of NMDC. TATA Steel has also similar facilities at Joda mines.

Recently RDCIS of SAIL has developed one innovative slime beneficiation plant at Dalli mines of Bhilai Steel Plant. Similar work has also been done at iron ore mines of M/S Sesa Goa and Fomento in Goa region.

International

At the international level Australia, Brazil, Russia, Ukraine are the major countries producing different grade of iron ores, some for their internal consumption and some for export. There are two major differences between the iron ore of India and other countries. One is the Fe content and presence of gangue material particularly silica and alumina and the other is the generation of fines and micro-fines and their beneficiation. The generation of fines from iron ore mining in other countries is <20-25% and slimes <10% which is much less in comparison to the generation in India.

The basic technologies adopted for beneficiation are the same but over the years unlike in our country there has not been any accumulation of low grade fines, slimes and waste in their tailing ponds. Advance and improved version of magnetic separation and hydrocyclon are used for beneficiation of low grade fines and slimes.

SWOT Analysis

Strength

Latest research work has been carried out in the field of slime beneficiation at Dalli mines of Bhilai Steel Plant and is operating since 2008-09 and the plant is producing at the rate of 40 ton/hour. The collaborator IMMT, Bhubaneswar has been very actively involved in conducting similar research work in their mineral processing department.

Weakness

The most important weakness of the present research is that it is confined mainly to beneficiation of slimes containing hematite ore. Iron ore slime containing goethite and of very fine size that is below 45 microns is still unattended. Combination of goethite and alumina bearing gangue phase in slime is typical of Indian iron ore slime.

Opportunity

Huge deposits of iron ore slimes are lying in the tailing ponds of Barsua mines of RMD. With the successful commissioning of the plant, Barsua mines will be able to enhance the supply of fines to Rourkela steel plant. About 100 million tons of dumped lean quality iron ores are lying at various mine heads of SAIL and conversion of these wastes to valuable input feed for making steel. There will be great saving from cost point of view. After successful commissioning of plant at Barsua, RMD division of SAIL will be able to liquidate the huge accumulated stock of slimes at other mines. There will be added advantages for environment protection.

Threat

Due to huge deposit of iron ore slimes in tailing ponds of Barsua mines and if these slimes are not beneficiated there is apparent threat from pollution control authorities and there may be chances of disruption in normal operation of mines.

Enablers:

There are inferior physical and chemical qualities of Barsua iron ore. Source for production of iron ore concentrate (feed for new pellet plants), threats from pollution control authorities, huge accumulation of slime in tailing ponds, mineral conservation and increase in Blast Furnace productivity are other enabling factors. RDCIS, Ranchi over the years has developed excellent expertise in doing the work on mineral processing. It has well equipped laboratory with all sophisticated and advanced equipment required for present days research work.

Disablers:

Large generation of slime during wet operation, difficult to upgrade highly aluminous ore, size fraction (below 45 microns size) are the important disabling features of slime beneficiation.

Techno-Economic Assessment:

Following benefits are envisaged after successful commissioning of the project: there will be extra fines production of 50 ton/hour by reducing slime loss from 28% to 14% level.

There would be increase in overall Fe% in iron ore fines up to 61% to 62% Fe. Additional mineral conservation will be there due to recovery of concentrate from slimes. This would lead to environmentally friendly process.

It is believed that after the successful completion of the project it will be beneficial for iron ore mining. Considering the cost of fines at @ Rs. 427/ton (08-09), the revenue generation will be around Rs.21,000/ hour. Also keeping in mind 50% of ore being processed through wet mode and considering 12 hours operation per day for 150 days operation, 1800 hours operation is expected at slime beneficiation plant i.e. Revenue generation due to extra production will be around Rs. 3.78 Crore/year.

Also, from improvement in blast Furnace productivity due to increase in 0.25 % FE in Blas Furnace burden, nearly Rs. 1 Crore/ year is expected from Rourkela Steel Plant. The overall revenue generation would thus be around Rs. 4.78 Crore per annum.

Conclusion:

The project initiatives are in line with the objectives of the project. It is running behind the schedule by one year. On the coordination part of the project, it has established good working relations with the partner institutions.

India has a good quality iron ore reserves all over the country of about 14 billion tons. At present India is producing about 220 million tons of iron ore per year. According to report in Steel Insight, considering the GDP growth rate of 8% the projected requirement of iron ore by 2019-20 would be 500 million tons. The biggest challenge before Indian steel industry would be the input raw material security mainly the iron ore. Lump availability is decreasing and with mechanized mining generation of low grade fines which cannot be used for sintering is increasing. As a result more than 100 million tons of dumped fines and slimes (low grade iron ore) are accumulated at the various mines of SAIL. Even 20 million tons of slimes are accumulated at the various mines of NMDC. Three new blast furnaces of 4000 M^3 is coming at Burnpur, Rourkela and Bhilai steel plants. Corporate plan of SAIL has envisaged use of these low grade ores in future. To increase the perspective reserve and considering the overall scenario Indian Bureau of Mines (IBM) has brought down the cut-off level of Fe to 45%.

The capacity of Barsua mines is being increased from 2.5 to 4.5 million tons/year. Apart from increasing the capacity, all efforts are being made to beneficiate the slimes lying at the various mines of SAIL. To meet the increased demand of Rourkela steel plant after expansion. RDCIS has taken initiative to beneficiate the slimes lying at Barsua. Barsua slime has high alumina and Gibbsite and Goethite are interlocked in hematite matrix. Since liberation technique for Gibbsite separation is not well known suitable beneficiation process is being designed to recover iron ore fine concentrate ~ 64% Fe with Silica+ Alumina < 5% from slime/process rejects having 55-57% Fe at ~ 50% yield.

It is estimated that at the current level of iron ore production in India amount of iron ore lost in the tailing would be about 10-15 million ton per year with 55-60% Fe. There is a need to increase the reserve base and beneficiate low grade iron ore fines and slimes. The importance of this can be realized from the fact that 1% Fe increase in the Blast Furnace burden productivity increases by 2% and coke rate and lime stone consumption comes down by 1.8% and 0.9% respectively.[17]

[17]Steel Insights Report, 2012

B.6: Development of Pilot Scale Pellettization Technology

Project Title	: Development of Pilot Scale Pelletization Technology
Project Cost	: Rs. 41.89 Crore
Project Duration	: 42 months
Starting Date	: January 2011
Completion Date	: June 2014
Current Status of Project	: June 2015
Expenditure Incurred	: 2.6 Crore
Project Leader	: RDCIS, Ranchi
Associates	: IMMT, Bhubaneswar NML, Jamshedpur IIT, Kharagpur
Principal Coordinator	: Dr SK Pan

Project Objective:
Development of pilot scale pelletization facilities based on comprehensive laboratory scale trials backed with sound theoretical exercises and development of mathematical models for all steps of pelletization towards achieving the objective of setting up a commercial pellet plant for Indian Goethetic / Hematite ores with varying degree of fineness.

Project Basic:
Low grade iron ore, iron ore fines and iron ore tailings/slimes are accumulated over the years at mine heads and generated during the existing washing processes. There is a need to beneficiate these to provide concentrates of required quality to the Indian steel plants. Indian iron ore are fragile in nature and contain good amount of goethite and kaolin in association with hematite. During beneficiation of these low grade ores, goethite enriches itself and results in high Loss on Ignition (LOI). For solving the above detailed studies are needed to develop relevant technological parameters for producing heat hardened pellets from goethite/ hematite iron ores.

Project Deliverable: Advanced Pelletization Technology

Project linkage: Initially there was no linkage with any organization but ESSAR Steel has agreed for industrial trial at their Visakhapatnam Pelletization Plant

Project Approach:
A comprehensive and detailed approach has been adopted for the project. As per the proposal the project is to be executed by different organizations as per their area of expertise. Following agencies are involved in different activities according to its expertise:

RDCIS, SAIL

- Laboratory scale beneficiation and pelletization studies
- Setting up a pilot scale pelletization facility at RDCI, Ranchi
- Systematic trials based on bench scale parameters
- Comparative evaluation of Straight- grate and Grate-kiln process of pelletization

IMMT, Bhubaneswar:

- Generation of high LOI ore fines concentrate from low grade ore/ slime/tailings through beneficiation
- Characterization of high LOI fine concentrates
- Design& setting up fluidized bed roaster
- Pelletization studies on high LOI concentrate
- Pelletization study of roasted concentrate

NML, Jamshedpur:

- Bench scale pelletization and optimization of process parameters
- Bench scale indurations of green pellets
- Pilot scale pelletization and indurations of green pellets

IIT, Kharagpur:

- Design of straight-grate indurations furnace
- Thermodynamics studies on different phases of indurations
- Kinetic studies to estimate reaction in pellet formation
- Optimization of processing parameters of indurations cycle in straight-grate and grate kiln
- Structure-property correlation of hardened pellets

Existing Technology:
At present two processes are available for making pellets- one is Straight-grate process and the other is Grate-kiln process. Straight-grate process is suitable for all types of ores where as Grate-kiln process is normally adopted for magnetite ore fines.

Presently all the pellets plants in India are working on Straight-grate technology. Recently, two pellet plants have come up using the Grate-kiln process based on Chinese technology, one at M/S BMM Ispat and the other at M/S Xing India both in the Hospet region of Karnatka.

Iron ore fines from different mines of India, particularly, the typical Goethitic ones, have their own characteristics and need detailed investigation to establish the appropriate pelletizing parameters for selecting the appropriate pelletizing technology. There is no such comprehensive facility available in India to ascertain the type of the pelletization process to be adopted.

New and Improved Technology:

Before pellet making it is desirable to carry out a study in the area of ore characterization, beneficiation, grinding of ore fines, green pellet preparation and development of indurations cycle for pellets for which the existing laboratory facility will be augmented.

RDCIS, Ranchi has incorporated the improved design of movable pot grate system for heat treatment test of green pellets under this project.

IMMT, Bhubaneswar is developing new technology based on fluidization technology for the roasting of the goethite present in the iron ore concentrate, whereby there will be sufficient reduction in Loss On Ignition (LOI).

NML, Jamshedpur is coming with an improved process for indurations of green pellets, based on optimizing the thermal cycle of pre-heating, firing and cooling to generate heat hardened green pellets with sufficiently high crushing strength.

There are other technologies available on which many pellets plants have been set up and many are being setup in India. Some of them are; Siemens Metal Technology (Circular Pelletiization technology), Ototec-Germany, Stemcor, METSO, AISCO-1.2 million tons per annum Grate Kiln Technology, Chinese Technology etc. Recently MECON Ranchi has also collaborated with a Chinese company for setting up a pellet plant of 1.2 million tons per annum capacity. Lot of modernization / modification work has been done indigenously at various installed plants which are in operations for many years.

Status of work done in national/international Arena:

National

Conventional pelletization plant of straight grate machine was first installed by Kudremukh Iron Ore Company Limited (KIOCL) at Mangalore suitable for magnetite ore which was later modified for hematite also. The 3 million tones capacity plant of KIOCL has a pilot scale heat hardening facility along with laboratory facilities for 80 kg batch. Other operating plants are JSW Vjaynagar, ESSAR Steel at Vizag (8 million tons) and Paradeep (6 million tons).

Recently one 6 million tons pellet plant has been commissioned at TATA Steel Jamshedpur besides the plants set up with Chinese technology. Apart from the above technologies, lot of pellet plants based on the technology supplied by Germany and Canada are coming in India.

International

Several fundamental studies have been carried out in China, Japan, USA and other countries in the world on various parameters of pelletization viz. reduction kinetics of iron ore-carbon materials composite pellet, rate of reduction of different additives, heat conservation, heat transfer and shrinkage of the pellets etc. METSO has done work on laboratory scale pelletization plant.

In China feed material for pelletization is magnetite ore whereas in India most of the plants are now being designed based on hematite ore. Now suitable modifications are being incorporated in the basic design that plants can be operated with both hematite and magnetite iron ores.

SWOT Analysis:

Strength

In the past RDCIS, Ranchi has carried out similar work in the field of slime beneficiation at Dalli mines of Bhilai Steel Plant which is the basic feed required for pelletization. Some success has already been achieved. RDCIS has undertaken R&D projects in diverse realms of Iron & Steel Technology under the categories of Plant Performance Improvement, Product Development, Scientific Investigation and Development, Basic Research and Technical Services. The collaborator IMMT, Bhubaneswar and NML, Jamshedpur are actively involved in conducting similar research work in their mineral processing department.

Weakness

Most of the data are based on the details collected from KIOCL, Mangalore plant. Iron ore slime containing goethite are of very fine size that is below 45 microns.

Opportunity

Huge deposits of iron ore fines, slimes are lying in the tailing ponds of various mines of RMD, SAIL. As per corporate plan of SAIL, pellet plants are envisaged at various mines. Hence developing suitable pelletization technology will give required inputs, which will help in successful commissioning of the pellet plants. It is being considered that in future about 70% of steel capacity is going to be based on pellets so that there is a huge opportunity for the research and development of pelletization technology in India.

Threat:

There are huge deposits of low grade iron ore fines and slimes in tailing ponds of various mines and if these are not beneficiated and converted to pellets there is apparent threat from pollution control authorities and there are chances of disruption in normal operation of mines. Already some mines have been served notice by Jharkhand pollution control authority for violating various norms.

Enablers:

Many factors are proving to be enablers in the development of pelletisation technology like, fast depletion of iron ore lump, use of low grade fines in future, limited use of micro-fines in sintering, increased Blast Furnace Productivity and stress on green manufacturing of steel. Further, RDCIS has huge experience and expertise in doing the work for mineral processing. The department has well equipped laboratory and all modern and sophisticated machines used for present days research work are available.

Disablers:

Some of the disabler factors in the process of developing pelletization technologies are Goethite ore fines which contains about 6% chemically bonded water, extra heat required for induration, disintegration of pellets because of water separation above 400-500 ^{0}C and CO_2 emissions. Moreover, since SAIL does not have its own pellet plant, not much work has been done at pilot scale by RDCIS in the field of pelletization.

Techno-Economic Assessment:

Though it is very difficult to make assessment on economic basis but general belief is that pellets improve the Blast Furnace performance in many ways like: higher iron content per unit furnace volume due to high bulk density, more permeability in the stack region resulting in uniform pressure drop, high strength and higher softening temperature compared to lump ore.

It has been found out that 10% pellets in the burden increases the blast furnace productivity by 3% and decreases coke by 2.5%. Because of the various advantages now there is trend of increasing pellet charging in the Blast Furnace burden. ESSAR Steel is planning for almost 100% pellet charging in Hot Metal Production through blast Furnace and DRI route.

Conclusion:

The project initiatives are in line with the objectives of the project. Regarding the time schedule, the project has been delayed by about one year and is likely to be completed by June 2015. The coordination between the lead organization and associates is very good and they are coordinating well with each other in the fulfillment of the task assigned.

Ever since the cost of calibrated iron ore has shot up, the steel industry has started looking up for various alternatives to sustain market conditions. Utilization of low grade iron ore and iron ore generated fines through pelletization route has become the most viable option for Indian Steel industry. Areas where pelletization occurred recorded the highest value per ton of iron ore.

Low grade iron ore, iron ore fines and iron ore tailings/slimes accumulated over the years at mine heads and generated during existing washing processes, need to be beneficiated to provide concentrate. It is estimated that about 200 million tons of low grade iron ore fines and slimes are dumped at various mine heads. For using this fine concentrate, pelletization is the only alternative available. Thus, there is a need to investigate a pelletization technology which will be best suited for iron ore fines of SAIL mines.

As per M-Junction and Steel Insight estimation, in India present capacity of pellet plants is 30-36 million tons which is going to increase to 50 million tons in another two years and it is expected that the pellet plant capacity by 2015-17 would be about 80 million tons. Apart from new pellet plants being set up many producers are doing back ward integration and are setting up pellet plants. Various new plants which are coming in near future are Essar

Steel 6.0 MT, Bhusan Steel and Power 4.0 Mt, Jindal Steel and Power 4.0 MT, BRPL Stemcore 4.0 MT etc.

Shabro Metal & Technology Ltd. has claimed that in use of pellets as a feed material for making iron there are various advantages viz. specific consumption of coal can be reduced by 10%, campaign life can be increased by 60%, Refractory consumption may be brought down by 50% and maintenance and power consumption can be brought down by about 50%. Better environment to work is an added advantage.

B.7: CO_2 Abatement in Iron And Steel Production

Project Title	: CO_2 abatement in Iron and Steel production by process optimization
Project Cost	: Rs. 0.84 Crore
Project Duration	: 36 months
Starting Date	: January 2011
Completion Date	: December 2013
Current Status of Project	: Likely to be completed byJune 2014
Expenditure Incurred	: 0.80 Crore
Project Leader	: IIT- Kharagpur
Associate	: RDCIS, Ranchi
Principal Coordinator	: Prof. P. K. Sen

Project Objective:

The principal objective of the present project is to use a process optimization approach to minimize CO_2 by optimizing process parameters, thus setting the feasible limits of CO_2 in an existing integrated steel plant. Furthermore, the possibility to apply the model for other integrated steel plants will also be taken up.

Ongoing research at IIT, Kharagpur on the optimization of energy and CO_2 emission has shown that it is possible to create a combined optimization tool that is powerful to assess the system performance from several aspects for a steel plant.

Project Basic:

In manufacturing sectors iron and steel industry is one of the largest energy user in our country. According to IPCC, 4th Annual Report, (Working Group III on Climate Change for 2007) the Steel Industry represents 6 to 7% of global anthropogenic CO_2 emissions. According to the International Energy Agency (IEA) also it is around, one fourth to one third, of the whole industry sector. Considering the impact of CO_2 emission in atmosphere all efforts are being made for reduction of CO_2 either by process optimization or use of other production route using different process reductant. Best possible solution would be to reduce CO_2 emission by optimizing process parameters in existing plants, particularly in iron and steel zone.

Project Deliverable: Process optimization for reduction in CO_2 emission

Project linkage: No direct linkages but RDCIS, (SAIL) the collaborator has identified Rourkela Steel Plant for providing all necessary technical inputs for the research.

Existing Technology:
In any integrated steel plant, Blast Furnace is the most common route for production of molten iron and this is the area where maximum CO_2 emission takes place. All attempts are being made for reduction of CO_2 emission either by hydrogen bearing or by pulverized coal injection through the *tuyeres* in the existing operating Blast furnaces. Alternative direct smelting technologies like COREX, FINEX etc. are being used by different producers not only to cut down the cost of hot metal production but also to minimize energy and CO_2 emission. In the direct smelting processes coke has been replaced completely by different grades of coal

Till now, little effort has been made to predict CO_2 emission patterns from blast furnaces under various operating conditions. Different techniques are being used by various producers but these techniques are specific to a process and design and operating regime of different blast furnaces. Always there is a conflict between the cost of hot metal production and CO_2 emission but trade-offs between multiple objectives such as emissions and costs, energy utilization and material efficiency is being done to reach to a optimal conclusion.

Although tools would be specific to a process but based on the process data and basic models use of Artificial Neural Networks (ANN) tool is being done by suitably incorporating Genetic Algorithm (GA) methodology to arrive at process profitability.

New Technology:
Till now, a one-dimensional static blast furnace model, consisting of a mass balance and heat balance has been developed and was being used on wider level. The calculation method was based on mass/energy balances and carbon/oxygen balances.

In present study, Blast Furnace has been divided into various zones which enable to determine heat losses separately in each zone. It is assumed that in the uppermost zone only gas phase reactions and reaction between gaseous and solid phase occurs and in the lower zones all top charged iron oxides are stage wise reduced to liquid iron.

The available model will be modified suitably based on progress of the project. The different steps would be:

1. Modification of the first principles model for blast furnace performance prediction, keeping in view the various operating parameters viz. production rate, coke rate, specific fuel consumption, flame temperature, top gas temperature, slag basicity, slag rate, top gas volume, top gas contents, heating value of top gas etc.
2. Validation of data collected in the plant.
3. Development of a linear regression model for output prediction.
4. Use of ANN techniques to develop the required correlations.
5. The economy of iron making in the blast furnace.
6. Development of a Pareto-optimal front.

Tools would be specific to a process but based on the process data and basic models, it is proposed to use in–house capabilities in GA programming and ANN application for arriving at solutions.

Status of work done in national/international arena:

National

Not much work has been done in India but an online control model is being developed along the lines of the modeling approach. However, this approach is not aimed towards optimizing CO_2 emission, etc.

International

The major work on the application of modeling to blast furnace for CO_2 minimization has been reported by Christer Ryman through the use of process integration methods.[18]

Limited data on comparative analyses of COREX and blast furnace of Green House Gases (GHG) is available. As pointed out earlier actual blast furnace data is not available readily to establish the modeling approaches developed and discussed in the proposal.

Report by Anne Carpenter reviews number of measures to abate and process CO_2 emission from the different steel making processes:

- Minimizing energy consumption and improving the energy efficiency of the process.

[18] Evaluation of energy and CO_2 emission strategies in Blast Furnace Iron making and Oxygen Steel making, Lulea University of Technology 2007

- Change to a full and / or reducing agent with a low CO_2 emission factor.
- Capturing CO_2 and storing.

SWOT Analysis:

Strength

The most important strength of the project after the development of optimization model for reducing carbon abatement would be broader application area in Iron and steel industry including mini blast furnaces and alternative smelt reduction processes. Various similar sponsored projects have been undertaken and executed in the past. The collaborator RDCIS has been very actively involved in conducting similar research work in various Blast Furnaces of different steel plants of SAIL.

Weakness

In this project entire data-base is collected from Blast Furnace of Rourkela Steel Plant, which may not represent entire range of operating parameters of Blast Furnace regime. The two objectives of Blast Furnace Operations are to minimize the specific hot metal production cost and the amount of CO_2 emissions are conflicting and hence the operating personnel of Blast Furnaces are serious. There is no consultancy arrangement with other consulting engineering organizations/national laboratories and institutions directly for this project. It is planned to take up future activities on commercialization through RDCIS-SAIL, preferably at a plant chosen by them.

Opportunity:

According to HU Changging, there is huge scope for reduction of CO_2 emissions in metallurgical steel plants. About 398 kg CO_2 can be reduced per ton of crude steel produced and about 400 khw electricity can be generated from per ton of crude steel produced.[19] Considering the huge potential available for reduction of CO_2 emissions in steel plants many new technologies may be introduced. Some of them are coke dry quenching, top gas recovery turbine and top gas recycling etc. Off-late there has been great emphasis on carbon capture and storage.

Threat

Various alternative technologies are available for the replacement of coke and reduction of CO_2 emissions in iron making. Trade–offs between multiple objectives is involved, such as emissions and costs, energy utilization and material efficiency.

[19] HU Changging, HU, HAN Xiaowei, LI Zhihong, ZIHANG Cunxia, ' *The Energy Analysis of a Blast Furnace System',* Journal of Environmental Sciences Supplement in 2009

Enablers:

There is growing concerns over climate change, stress on green manufacturing of steel, top gas recovery and recycling, and reduction in energy consumption. Metallurgical and Materials Engineering department over the years has developed excellent expertise in extractive and physical metallurgy and modeling and simulations. The department has well equipped laboratory with sophisticated machines like High resolutions X-ray Diffract meters, thermal analyzers, atomic force microscope, optical and electron microscope.

Disablers:

There is a conflict between cost of hot metal production and cost of CO_2 emissions. There is no direct linkage with any steel plant. It is a data driven model and may face multi objectives optimization problem.

Techno-Economic Assessment:

Since project is still in development phase, techno-economic assessment has not been carried out but indications are that with process optimization about 20-30% CO_2 emissions can be reduced and operating efficiency of Blast Furnace can be increased. However, full assessment can be made at the conclusion of this project only.

Conclusion

The project initiatives are in line with the objectives of the project. At the time of visit by the study team it was found that the project team have developed ANN module and data has been generated and process is in progress. The project was originally scheduled to be completed by December 2013 but it may take another 6 months in completion. The coordination between the lead organization and associate RDCIS Ranchi was found to be very good.

With the growing concerns over climate change, steel makers are facing challenges of finding means and ways of lowering CO_2 emissions without seriously undermining process efficiency and adding to the cost. After Kyoto protocol agreement, it became necessary to decrease CO_2 emissions produced by the iron and steel industry.

Carbon intensity varies between production routes ranging from, 0.4 ton CO_2 per ton of crude steel produced through EAF route,1.7- 1.8 ton CO_2 per ton of crude steel produced through integrated BF-BOF route and 2.5 ton CO_2 per ton of crude steel produced through

DRI route. After power plant the areas responsible for more CO_2 emissions are Blast Furnace, Sinter/Pellet plant and coke ovens. That is once we take care of Blast furnace major emissions are taken care of.

CO_2 emissions have become so important that, IEA Clean Coal Centre is now taking information from the member countries about analysis of coal technology, supply and use. Best Available Technology (BAT) viz. Coke Dry Quenching (CDQ), Top Recovery Turbine (TRT) and Top Gas Recycling have led to sufficient CO_2 emissions reduction over the last 30 years.

Though not much emphasis has been given on Carbon Capture and Storage (CCS), but now there is growing need of incorporating CCS to bring down the CO_2 emissions in steel plants across the country.

B.8: Production of Low Ash Coal from High Ash Indian Coal and Desulphurisation of High Ash North East Coal

Project Title	: Production of low ash coal
Project Cost	: Rs. 19.44 Crore
Project Duration	: 36 months
Starting Date	: January 2011
Completion Date	: December 2013
Current Status of Project	: Likely to be completed by March 2014
Expenditure Incurred	: Rs. 7.94 Crore
Project Leader	: IMMT, Bhubaneswar
Associates	: RDCIS, Ranchi NML, Jamshedpur CIMFR, Dhanbad NEIST, Jorhat CMPDI, Ranchi
Principal Coordinator	: Dr S K Biswal, Chief Scientist, Mineral Processing Deptt.

Project Objective:

The principal objective of the project is "Production of low ash (10% ash) clean coal (coking and non- coking) from high ash Indian coal, including beneficiation/desulfurization of North East coal and recovery of ultra fine non coking coal from washery tailings".

Project Basics:

Coal, the most important fossil fuel in India, is vital for its energy security and plays a major role in economic development of the country, with particular reference to metallurgical and energy sectors. Sixty percent of our energy requirement is met from coal. Most of the non coking coal has high ash content varying from 40-50%. In view of the growing demand of both coking and non coking coal in the country, there is no other option left than to beneficiate high ash coal using advanced techniques.

Project Deliverable: Process of low ash clean coal

Coal Scenario:

As per Energy Information Administration Report (EIA) of USA world coal reserve is 998 billion tons. The Indian coal industry is the world's third largest in terms of production and fourth largest in terms of reserves. Around 70% of total production is used for electricity generation, 17% for steel and remaining by cement and other heavy industries.

India has a reserve of about 257 million tons as given in table-1

Table : Coking and non coking resources of India

Sl. No.	Types of Coal	Reserves (Billion T)
(1)	(2)	(3)
1	Prime Coking	5.313
2	Medium Coking	25.255
3	Semi Coking	1.707
4	Sub Total Coking	32.275
5	Non Coking	234.934
	Total (Coking & Non Coking)	**267.21**

Around 88% of coal reserves come under non-coking coal category. Most of these types of coal have less calorific value due to high ash content. The production of cóal in 2006-07 was 434 million tons against a demand of 471 million tons. Coal consumption has gone up from 510 million tons in 2007-08 to 550 million tons in 2008-09. Coal requirement for the power sector has grown by about 10% in the 11^{th} five year plan (2007-12). Coal production will grow at a CAGR of 9% during 2011-12 to 2013-14.[20]

For non coking coal against the current requirement of about 150 million tons the present capacity is only 105 million tons and out of the total production only 20% is being beneficiated at present. The availability of low ash coking coals in India is decreasing sharply. At present the cut–off level of ash is13-18 %.There is urgent need to reduce the ash content ~10%. The demand for thermal coal and coking coal by power and steel sector will gain momentum in future.

Production of Clean Coal

Following three tasks have been proposed to be carried out as R&D activities, to develop indigenous technology to utilize effectively high ash and high sulfur Indian coal.

[20] Indian Coal Industry Forecast to 2013, retrieved from http://www.rncos.com/Report/IM280.htm on 22.6.2013

1. Process development for beneficiation of raw coking coal including fines to achieve 10% ash coal.
2. Process development for beneficiation of non coking coal and recovery of ultra fine coal from non-coking coal washery tailings to achieve 10% ash coal.
3. Beneficiation and desulphurization of high sulfur North East (NE) coal.

TASK 1:

Beneficiation of coking coal

Existing Technology:

Beneficiation of coking coal in India is being done by Coal India Ltd, SAIL, TATA Steel, and other industries having mining lease. Production is around 18-19 million tons against the demand of 25 million tones. The gap is met by import. Beneficiation of coking coal is carried out by gravity and floatation techniques or the combination of the two. Coarse and fine particles (3-10 mm) are being beneficiated by gravity process whereas ultra fine particles (0.5 mm size) are being beneficiated by floatation techniques. The selection of the process as well as equipment depends on the liberation size and characteristics of coal. Till today, conventional floatation circuit is being used to recover carbon value in desired quality. Good amount of coal is lost in floatation tailings. It can be improved further in floatation circuit by adopting advance column floatation technology.

At present about 20 washeries built around 1960 are operating under Coal India, SAIL and Tata Steel but because of conventional design and restricted to treat a particular size these are not able to meet the requirement of quality as desired by current steel producers. At present in India, low LVC coal is not being beneficiated. Recently IMMT, Bhubaneswar along with CIMFR, Dhanbad and NML, Jamshedpur has carried out R&D work on some indigenous coal and has established that by adopting suitable floatation techniques ash percentage can be brought to a level of 10-11%.

New Technology:

The performance of existing technology is not satisfactory as good amount of coal is lost in floatation tailings. It can be improved by using advance column floatation technology, which comprises of following steps:

ROM coal has to be grinded further for size reduction (below 13 mm). Next step would be reduction of misplacement of light weight coal in middling in heavy media cyclone. Further beneficiation of middling generated from heavy media cyclone, reduce the ash content using column floatation process and further reduction of ash content from physical process concentrate by chemical/biological leaching.

The new technology will help not only to make effective utilization of coking coal resource but also to substitute part of the imported coking coal demand.

Status of work done in national and international Arena:

National

IMMT, Jamshedpur along with CIMFR, NML, R&D centre of Tata Steel and SAIL has done some work on coking coal fines from washeries of BCCL, CCL and West Bokaro for reduction of ash content by floatation process using different types of reagents. The pilot plant of 3 tones capacity has been set-up at West Bokaro and Sudamdih to recover the coal from the floatation tailings. Washeries efficiency at various coal mines are deteriorating due to lack of proper maintenance, modification and modernization.

International

Since the quality of coal in Australia and New Zealand, differ from India, the exact practices adopted there cannot be compared exactly. However the technology adopted in Russia, Ukraine, Canada and USA are same. Even in these countries heavy media bath is used for the size of -150+12 mm to upgrade the coal from 48% ash to below 6%.

Task 2:

Beneficiation of non-coking coal:

Existing technology

Beneficiation of non-coking coal in India was not given due importance till last 10-12 years due to low value or inability to meet the cost of process. In the present scenario, some of the washeries have been set-up to beneficiate non-coking coal by Coal India Ltd. and private agencies at different places for supply of the beneficiated coal to different power plants, metallurgical and cement industries. The coarse size fractions are beneficiated using jig, heavy media bath and heavy media cyclone at present. In most of the cases the fine coal (below 1mm size) is not being processed and it is either rejected or partly utilized by blending with beneficiated coal on its ash content. Before making commercial washery the washability study on coal sample is essential to establish the washing potential to assess the economic feasibility of the process.

As a matter of fact, the optimal beneficiation of non-coking coal needs a special approach from that of coking coal. Indian coals are difficult to wash because of their close association and intermixing of the coal and inert matters. Maximization of the recovery of clean coal at desired ash content is the major concern for the washeries, The perfection in predicting the anticipated yield of clean coal is a pre-requisite step in treating coal in an existing washery or in designing a new plant.

The investigation carried out at IMMT, Bhubaneswar has indicated that non coking coal can be beneficiated by using advanced floatation techniques. Besides the use of non-coking coal in power generation, its demand in metallurgical sector is also increasing.

New Technology:

ROM coal has to be grinded further for size reduction based on washability characteristics. Next step would be reduction of misplacement of light weight coal in middling in heavy media cyclone or heavy media bath. Beneficiation of -1 mm size coal generated from the washery using advanced gravity and floatation techniques, further reduction of ash content from physical process concentrate would be by chemical/biological leaching.

Status of work done in national and international Arena:

National

The quality of non-coking coal in India based on its calorific value is different from that of USA. Specific gravity of Indian coal is very high whereas in the USA coal it is very less. This is the main reason of difficulties to make sharp separation of gangue minerals from Indian coal.

Several projects have been sponsored by CMPDI, ACC, JSPL and Bhusan Steel. IMMT has been studying the characteristics of non- coking coal for the last four decades. The beneficiation studies both dry and wet have been carried out. IMMT, Bhubaneswar has developed the process to improve the floatability of oxidized non-coking coal for floatation of fine coal. Depending upon the quality, dry and wet beneficiation mode is selected.

Lot of investigations have been carried out to beneficiate non coking coal by different laboratories and technical institutions in India at both coarser and finer sizes either by dry or wet methods. The result indicates that ash content can be reduced to 25% and the product can be used for metallurgical industries.

The beneficiation studies on non coking coal from Bolanda mines and Talcher coal field were carried out using Hartz jig, the result indicated that product can be used directly for metallurgical and cement industries.

Further experiment has been carried out and it has been established that ash percentage can be brought down by finer grinding of coal and beneficiating by two stage floatation column. Ash percentage can be reduced to 15% with mm 55-56% yield and the product is better suitable for coal injection by blending with low volatile imported coal.

International

Dry coal beneficiation was popular in 1960s and it reached its peak of 25 million tons per year in USA in 1965 and accounted for 30% of coal preparation plant feed in UK, Canada and in the USSR in 1966. After mechanized mining dry beneficiation has lost its importance as ROM coal has lot of fines. Still all over the world, the people are working on to make it a cost effective process using different techniques. Significant development work in dry beneficiation is in progress in Canada, China, Germany, Belgium and other countries.

Task 3:

Beneficiation and desulphurization of NE Coal:

Large scale removal of sulfur, both pyritic and organic, by microbiological methods. The process will be tested for NE coal.

Existing technology

High sulfur in NE coal (>1 % up-to 10%) creates a serious problem in coal incineration in thermal and power plants due to SO2 emission. Due to environment protection requirement, sulfur content in burned coal should not exceed 1 %. The general trend is to reduce the permissible sulfur content to <0.45%. Optimum solution would be coal desulphurization before sending the sulfur free coal to end users.

In India about 134 million tons of coal containing 2-10 % sulfur is available in Assam region. Major portion 70-75% is organic sulfur.

New Technology:

In the current practice only physical and chemical method is used for desulphurization of NE coal. By physical method only bigger crystal of pyrite can be removed while finely disseminated and framboidal forms remain in coal. These forms and organic sulfur can only be removed by microbial methods, column and bioheap leaching etc. Microbial process for removal of coal will increase in waste utilization, improvement in productivity and reduction in emissions and pollution control.

Work done in national and international arena:

National

Earlier some work in this area was done by some CSIR laboratories and IISC, Bangalore to remove sulfur from Assam coal but the result showed that organic sulfur remained unaffected. In the recent past by using microbial treatment it has been found that 80-90% inorganic sulfur can be easily removed. Although work on organic sulfur removal from coal has been attempted with bacteria but little work has been done with fungi. IMMT Bhubaneswar has developed several processes on microbial desulphurization of coal and lignite on laboratory scale. NML, Jamshedpur has also developed processes on bio-leaching. Under Coal S&T grant, lot of work has been done on this by CMPDI

International

Similar work has been done in USA, UK, China, Indonesia, and Malaysia. China and UK have also collaborated to investigate means of reducing sulfur from Chinese coal. Bio-density desulfurization work has been done by Cranefield Univsersity UK. Similar work has been done by US Steel Corp. Research lab, Monroeville on Illinois No.6 coal. Experiment has been done in South Africa on their coal by using low power microwave energy.

SWOT Analysis

Strength

Mineral processing Divisions of the all the organizations are contributing immensely in the subject matter and have tie-up with end users both in public and private sector. The laboratories have expertise in conducting technology oriented programmes in mining and mineral processing. All the associated institutions have adequate capability and are doing research work in the related field.

Weakness

There is delay in converting lab scale to pilot scale and pilot scale to commercial scale. Due to lack of clear cut guidelines and delay in decision making there is delay in project implementation. There has been slow response from various organizations like Coal India , SAIL and other private sector companies who have mining lease are not serious for making modifications in washeries. Even proper care is not being taken for washeries maintenance.

Threat

Excessive government regulation continues to be a major concern for the Indian coal industry. Excessive legislative framework restricts the private sector in the establishment of coal washeries.

Opportunity

Utilization of high ash non-coking coal after beneficiation has good opportunity. The main objective should produce more yields preferably more than 75%. The rejects should have low carbon content and high ash >80%. The overall objective of non-coking coal utilization in various sectors should be according to the desired quality as given below:

Power generation	<34% ash
Sponge iron	<26% ash
Cement	<25 % ash
Corex process	<20 % ash
Romelt process	< 30 % ash
Blast Furnace injection	< 16 % ash

Enablers

All the four research labs of CSIR viz. IMMT, NML, CIMFR, NEIST, are well equipped and capable of doing experiment in the related field and have highly experienced scientist working on the projects.

Disablers

Low quality and high ash content is a problem. Coal washeries operating particularly under Coal India, are based on old technology and have not been upgraded /modernized. Stringent Govt. regulation may be the other disabler.

Techno-economic Assessment:

Techno economic assessment has not been done. It can be carried out based on the results of pilot scale study in association with CMPDI. It is estimated that in coming years India will be importing about 40 million tons of coking coal from Australia, New Zealand, USA, Canada, Russia, Ukraine South Africa and other countries at an estimated cost of 125 billion rupees. Beside import of non coking coal will also increase substantially in the coming year. As the demand of low ash coal is increasing for metallurgical purposes for coke making, blast furnace injection and other smelting process, there will be huge saving of foreign exchange when we increase beneficiation of coal.

Conclusion:

The project initiatives are in line with the objectives of the project. The project has been delayed by about three months and is likely to be completed by March 2014. The coordination between the lead organization and associates is very good.

India has a reserve of 32 billion tons of coking and 221 billion tons of non coking coal. In 2011-12, import of thermal coal and coking coal were 71.52 million tons and 31.1 million tons respectively. It was estimated that in 2012-13 total coal import would be 140 million tons. At a monthly average of 11.4 million tones, total 102.7 million tones have been imported in first 9 months of 2012-13- a jump of 18% on year to year basis. Thermal coal accounts for 70% of total coal import. Against an expected production of 574 million tones, there is going to be a shortfall of 192 million tones. The importance of beneficiation can be realized from above figures and growing demand in coming years.

The economic as well environmental benefits of using beneficiated coal in steel sector, cement and sponge iron industries have been established but the need of more and more washeries is to be given due importance. Washability characteristics of the raw coal should be the prime criteria in selecting the washing circuit.

By proper physical, chemical and biological desulphurization lot of NE coal can be used for PCI in Blast Furnaces, This will cut the import bill of integrated steel plants in India. By 2016, India is expected to become world's 2nd largest crude steel producer and as per the projections by 2020, India is expected to import whopping 83 million tones of which would lead to the green production of coking coal (apart from 10 million tones of PCI coal) equaling foreign exchange outgo of atleast14 billion USD per year.

93 million tones of metallurgical coal import implies that 50 % of India's steel production is dependent on imports, which means that there is high risk exposure. One of the important way forward will be to develop better technologies to beneficiate inferior grade coking coal. Therefore threats/ issues of heavy dependence on coal import should be met by removing road blocks in indigenous supply by beneficiation of both high ash coking and non coking coal.

Utilization of non-coking coal in metallurgical industries can be increased, with proper beneficiation and bringing ash level < 13 %.This non-coking coal can be used for- sponge iron making, coal injection in Blast Furnace, COREX Process and ROMELT Process. If non coking coal is beneficiated to meet the desired quality there will be huge saving in foreign exchange which is spent in importing PCI/CDI coal.

PART C

a. Conclusion

The combined R&D Investment in India in the Iron & Steel sector is very low at present as compared to other major steel producing countries. The Ministry of Steel has taken initiative to launch a scheme to give thrust to R&D in the sector. The need to have this scheme arose due to non-satisfactory outcomes from the older scheme of R&D Promotion from interest proceeds of the SDF. The scheme however, may slightly be modified. While the Ministry has tried to engage both bigger and smaller players and tried to incentivize the R&D through SDF assisted scheme earlier and this scheme now, at this stage it cannot be said that all the stakeholders especially the big private steel producers like Tata Steel, Essar Steel or JSW are on board. The smaller players have their limitations in participating in the scheme. The Ministry has also taken up other several capacity building initiatives like establishing Centre of Excellence, Steel Chair Professor, scholarships to students etc. However, if the R&D investment is to be increased, all the players need to be engaged on a continuous basis. This may require incentivizing investments through not only this scheme but also other policy measures.

At the same time the scheme needs to be continued, albeit with modifications, in view of the following:

1. In all the major steel producing countries the government support is massive, despite most of the production being in private hands.
2. Governmental support is also important in R&D because the gestation period from lab to plant is very long in the sector. The private players, especially the smaller ones, may not have the capacity to engage in such processes on their own.
3. This scheme is the only support to R&D in the sector in India, as SDF has not yielded desired outcomes and the scope in that is very low. In fact, there is even scope for higher budgetary support for the scheme.
4. If the growth targets in steel production are to be achieved and the kind of requirements that we may have in future because of development, investment in R&D is imperative.
5. Technology import has two constraints-first, if appropriate for India, it may be very costly and second our concerns are different from the concerns of other major steel producing countries.

6. The government needs to engage with all the stakeholders to give direction to R&D as per national priorities.

b. Recommendations

1. There is need to operationalize strategy for short term and long term programmes, as per the Roadmap, for providing financial support under the scheme.
2. The Ministry besides directly funding research studies in thrust areas should also take promotional measures to give thrust to R&D activities. These promotional measures may be through creation of an enabling environment, which may be the fourth objective of the scheme. It could be in the form of Annual Conference / Stakeholders' Meet where besides the organizations and institutions engaged in the projects sanctioned under the scheme, other stakeholders like industry chambers, small and big steel producers, Ministry of Coal, other potential R&D institutes etc. also participate.
3. The Ministry may, in consultation with experts and other stakeholders may also explore other measures too to ensure continuous engagement of all the stakeholders.
4. Though the scheme does not identify outcomes of the scheme, it may be appropriate to mention 'increased R&D investments' as outcome of the scheme. Some timelines may be determined. For example, achieving 1% of sales turnover by the terminal year of 12th Plan, could be the starting point.
5. Another outcome for the scheme could be in terms of researches leading to commercialization. While it is difficult to suggest a number, experts say that at least one out of 4-5 research projects should reach commercialization stage. Continuous engagement with all the stakeholders may facilitate this.
6. Calls for research proposal should be advertised extensively not only on the Ministry's website but also in leading newspapers and major journals. Research grants is a very effective incentive for all the major research institutions which may be possible only if they are aware about such source. Advertisement of the scheme may be effective in creating this awareness.
7. Evaluation criteria for studies should be laid down at the stage of solicitation of proposals itself so that they are known to all the applicants.
8. A technical session should be held between advertisement for soliciting the proposals and last date of submission of the research proposals to enable the

applicants to tailor their research proposals as per industry's requirements. This technical session should have extensive participation by all stakeholders. The Ministry conducted such stakeholders meeting and should continue doing that for the benefit of research institutions and the industry.

9. Conditions for award of research contracts like ownership of physical and intellectual assets should be laid down at the time of advertisement itself. DSIR and DST guidelines may be seen by the Ministry in designing its contract for award of research projects.
10. Condition of ceiling of 50% contribution to capital expenditure may be done away with and contribution may be in terms of percentages, where cost of providing plant facilities, technical services and manpower etc. by the commercial organizations is also factored in.
11. The Ministry may revise the guidelines for financial reporting and make it on quarterly or six monthly (preferable) basis, if not on yearly basis.
12. The study team is of the opinion that in view of there being a system of internal reviews as well, the frequency of review by PRC may be twice in a year.
13. The periodicity of PRC review may be determined in accordance with the timelines of respective projects.
14. The persons involved with the projects should not be the members of PRC, as this would be 'conflict of interest'.
15. The Ministry may examine the feasibility of having experts in the sector as the chairperson of PRCs.
16. There should not be more than two reviews projects on a given day. That would give sufficient time for discussions as the suggestions given by the PRC members are very valuable.
17. The PRC may identify criteria / indicators while reviewing the projects and be it made known to all.
18. It would be appropriate to earmark certain percentage of scheme budget for administrative expenses like organizing meetings or paying honorarium / sitting charges to non-official members and also for monitoring the projects in between the reviews.
19. The manner of engagement of smaller players may be determined in consultation with them. Some experts suggested that these companies may contribute to the

general pool of the scheme and be assured of royalties from the commercialization of the projects funded under the scheme and also royalty free use for themselves.

20. The Ministry may explore avenues like Corporate Social Responsibility to mobilize funds from private players for contribution to R&D. There are studies which indicate that R&D may be considered part of CSR, provided it is for societal benefits (Annexure 1a, 1b and 1c). If required, it may be further clarified either with the Ministry of Corporate Affairs or Ministry of Law.

Annexure - 1a

Corporate Responsibility and Environmental Research and Development

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September 4, 2003

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Annexure - 1-b

WHY IS R&D AN ESSENTIAL PART OF CSR?

Blog Entry by Akhila Vijayara... (/users/akhila-vijayaraghavan) in Corporate Social Responsibility (/blog/category/corporate-social-responsibility)

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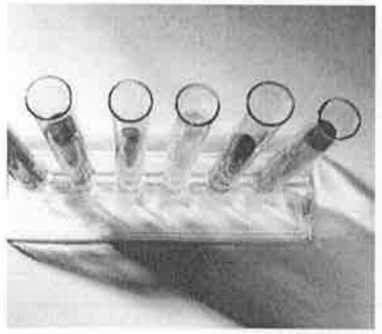
18, 2011 - 6:16am



Recently a random Poll Survey of Associated Chambers of Commerce and Industry of India said that 46% of the CEOs of Indian companies spent less than 1% on R&D in the year 2009-10. The survey also found that the 27% of private sector firms have started improving the R&D spending. This will help in new product development and enhance competitiveness in the global arena.

The survey pointed out three sectors; pharmaceuticals, automobiles and software where Indian industry has increased spend on R&D. The lack of focus on R&D has affected industrial competitiveness in India in comparison to countries like Taiwan, Singapore, Israel and Korea. Many CEOs opined that if India Inc has to become globally competitive, it has to raise the R&D expenditure and focus on new product innovation.

Another point on the survey included the profile of CSR. 72% of CEOs felt that the CSR should be made mandatory (http://www.justmeans.com/CSR-Mandating-without-mandating/41644.html) to strengthen their brands and appear to be people friendly Socially ...sible identities. It also highlighted that the number of companies which are practicing CSR is also growing.

...EOs feel that CSR is the way for companies to meet wider obligations. According to them these include employees as well as the wider community. ...ies are beginning to realize that their activities have an impact on the society in which they operate.

... part of industry operation that is essential for improved business competitiveness. However it is also a part of CSR and it is not often acknowledged as such. R&D in addition to developing newer products also improves product design to be more environmentally compliant - the safety and environment aspect of new design fits in well with CSR requirements.

Safety and environmental compliance forms a large part of not only CSR but also ideal company operations. R&D also supports the marketplace aspect of CSR by ensuring that products meet stringent quality controls. By ensuring safer products, companies can also boost their consumer base.

Socially responsible corporate investments in environmental R&D especially will increase corporate self-interest in reducing pollution caused by toxic emissions. Consequently, corporate environmental R&D investments depend on both public policy and the structure of markets.

Both R&D and CSR activities can create assets that provide firms with competitive advantage. Furthermore, the employment of such activities can improve the welfare of the community and satisfy stakeholder expectations, which might vary according to their prevailing environment. R&D intensity has varying effect on CSR across both manufacturing and non-manufacturing industries. Investment in R&D intensity will positively affect CSR especially in the manufacturing industries.

Boosting R&D efforts is something that CSR managers should think about because it indirectly also boosts CSR efforts.

Photo Credit: Amgen

Corporate Responsibility (/blog/tag/corporate-responsibility) • CSR (/blog/tag/csr) • CSR reporting (/blog/tag/csr-reporting) • CSR Reports (/blog/tag/csr-reports) • Good work (/blog/tag/good-work) • Initiatives (/blog/tag/initiatives)
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Annexure -1c

Documento de Trabajo13/09

THE EFFECT OF R&D INTENSITY ON CORPORATE SOCIAL RESPONSIBILITY

Robert C Padgett
Universidad de Salamanca
José I. Galán
Universidad de Salamanca

Abstract

This study examines the impact that Research and Development (R&D) intensity has on Corporate Social Responsibility (CSR). We base our research on the Resource Based View (RBV) theory, which contributes to our analysis of R&D intensity and CSR because this perspective explicitly recognizes the importance of intangible resources. Both R&D and CSR activities can create assets that provide firms with competitive advantage. Furthermore, the employment of such activities can improve the welfare of the community and satisfy stakeholder expectations, which might vary according to their prevailing environment. As expressions of CSR and R&D vary throughout industries, we extend our research by analyzing the impact that R&D intensity has on CSR across both manufacturing and non-manufacturing industries. Our results show that R&D intensity positively affects CSR and that this relationship is significant in manufacturing industries, while a non-significant result was obtained in non-manufacturing industries.

Keywords:
Competitive Advantage, Corporate Social Responsibility, Industry, Resource Based View Theory, Research and Development.

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Annexure 2

LIST OF PERSONS CONTACTED DURING THE STUDY

Interactions were held with all the officials mentioned in the list.

Name	Designation and Address	Contact Details
Ministry of Steel, Government of India, Udyog Bhawan, New Delhi		
Shri Suraj Bhan, I.E.S	Economic Advisor	Tel: 23063020 Fax: 23061409 Email: suraj.bhan@nic.in
Shri U.P. Singh, I.A.S.	Jt. Secretary	Tel.: 23061064
Shri A.C.R. Das	Industrial Advisor	Tel.: 23063170
Shri Harihar Mishra	Under Secretary	Tel.: 23061479
Shri S.K. Bhatnagar	Deputy Industrial Adviser	Tele: 23062490 Fax: 23063236 Email: shakubha@hotmail.com
Shri A. Das	Senior Manager, SAIL	Tel.: 23062490 Email: das.amitayu@gmail.com
CSIR – Institute of Minerals & Materials Technology, Bhubaneswar		
Prof. B. Mishra	Director	
Dr. Bhagyadhar Bhoi,	Principal Scientist Advanced Material Technology Department	Tel: 0674-2581635, 36 (Extn. 239) Fax: 0674-2581066, 2581637 Email: bbhoi@immt.res.in, bbhoi@yahoo.com
Dr. S.K. Biswal	Chief Scientist Mineral Processing Department,	Tel: 0674-2379455 Fax: 0674-2379637 Email: skbiswal@immt.res.in, skbiswal1@yahoo.com
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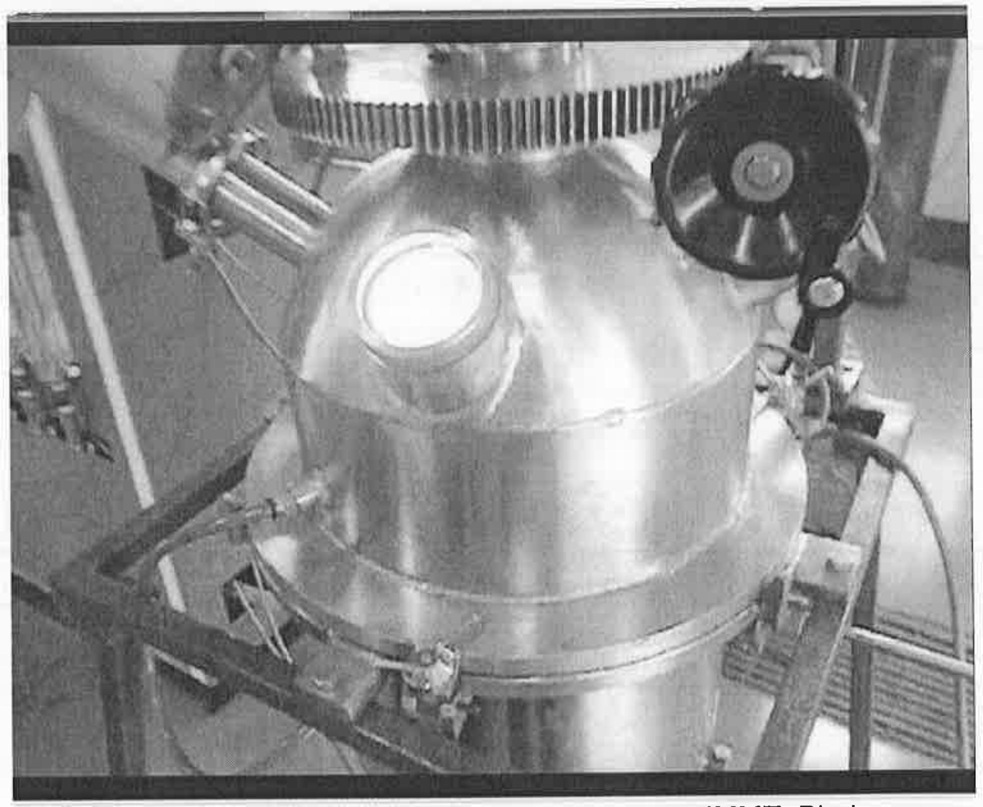
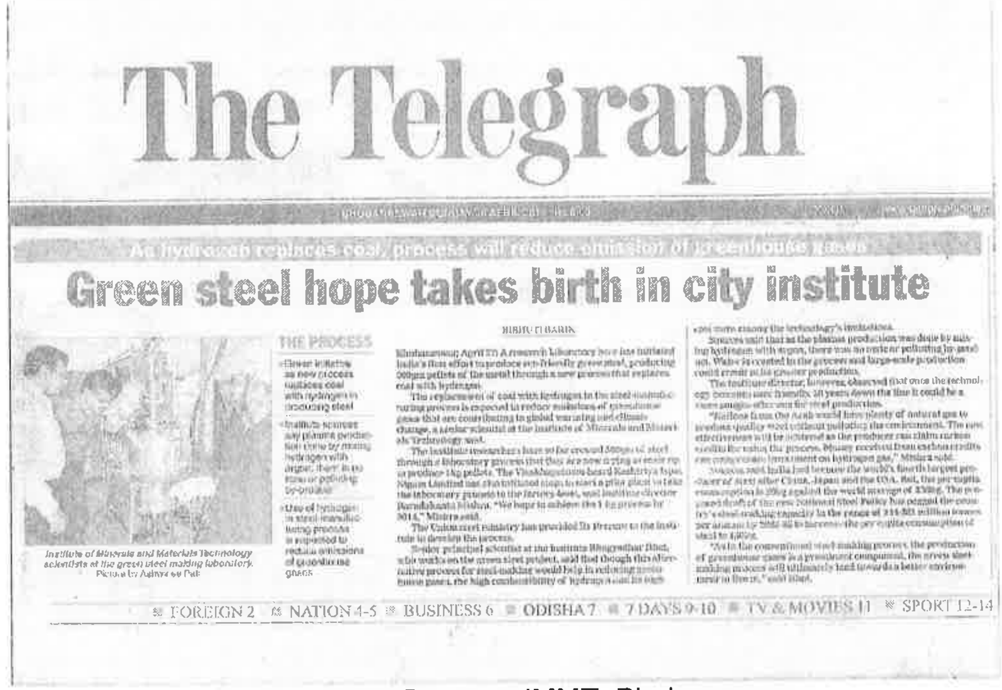
Dr. P. Sita Rama Reddy	Chief Scientist & Head Mineral Processing Department	Tel: 0674-2379536 Fax: 0674-2567650 Email: psrreddy@immt.res.in
R&D Centre for Iron & Steel, Ranchi		
Shri Sridhar Varadarajan	Executive Director Incharge	Tel: 0651-2411124, 2411126 Fax: 0651-2411090, 2411103 Email: svrajan@sail-rdcis.com
Dr. S.K. Pan	DGM	Tel.: 08986880144 Email: skpan@sail-rdcis.com

National Metallurgical Laboratory, Jamshedpur		
Dr. S. Srikanth, FNAE	Director	Tel: 0657-2345202, 2345028 Fax: 0657-2345213 Email: director@nmlindia.org, ssrikanth@nmlindia.org
Dr. K.K. Bhattacharya	Chief Scientist Mineral Processing Department	Tel: 0657-2349001, 2349023 Fax: 0657-2345213 Email: kkb@nmlindia.org, kkbhattacharyya@yahoo.com
Dr. Ratnakar Singh	Dy. Director & Head Mineral Processing Division	Tel: 0657-2345054 Fax: 0657-2345055, 2345213 Email: rs@nmlindia.org, ratnakarsingh15@gmail.com
Dr. Abhimanyu Das	Principle Scientist Mineral Processing Division	
Dr. R.K. Minj	Principle Scientist Mineral Processing Division	
Dr. M.K. Mohanta	Principal Scientist Mineral Processing Division	Tel: 0657-2349003 Fax: 0657-2345213, 2345245, Email: mohanta@nmlindia.org, mkm_nml@yahoo.co.in,
IIT Kharagpur		
Prof. P.K. Sen	Chair Professor Department of Metallurgical & Material Engineering,	Tel: 03222-281760 Fax: 03222-255303, 282280 Email: prodip.sen@gmail.com pksen@metal.iitkgp.ernet.in
Central Mining and Fuel Research Institute, Dhanbad		
Dr. T. Gauri Charan	Scientist	Ph.: 0326-2388310
Mr. G.K. Bayen	Scientist	
Dr. K.M.P. Singh	Scientist	
Dr. Kamal Sharma	Scientist	
Mr. U. Chatopadhyay	Scientist	
Dr. K.M.K. Sinha	Scientist	
Other Stakeholders		
Dr. Sanak Mishra	Member, PRC Vice President CEO, Greenfield Projects India ArcelorMittal, New Delhi	Tel.: 46759402 Fax: 46759494 Email: sanak.mishra@arcellormittal.com



Replacing Carbon with Hydrogen for Steel Making at IMMT, Bhubaneswar



The Telegraph

As hydrogen replaces coal, process will reduce emission of greenhouse gases

Green steel hope takes birth in city institute

THE PROCESS

Institute of Minerals and Materials Technology scientists at the green steel making laboratory.

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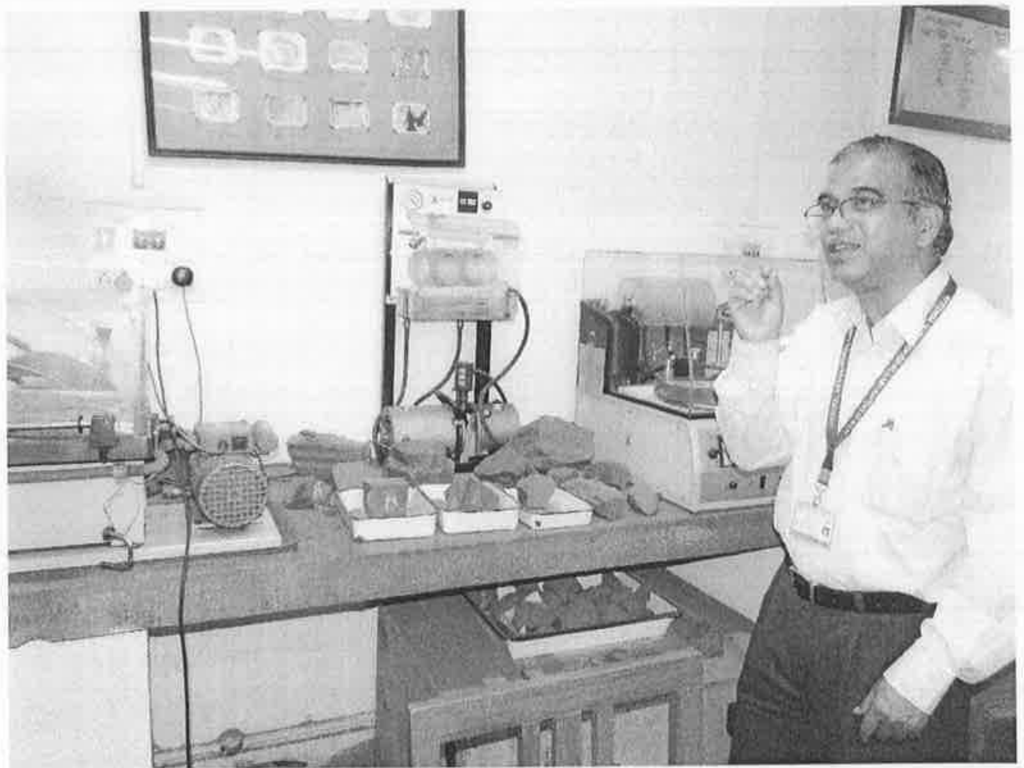
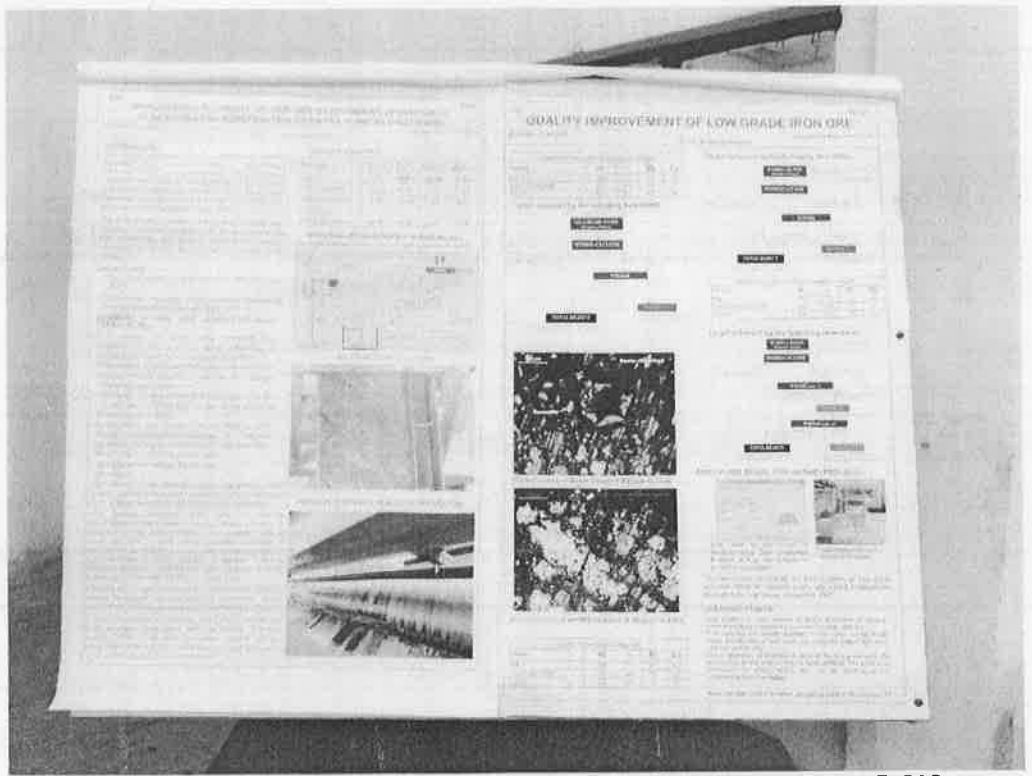
Project of the Future at IMMT, Bhubaneswar

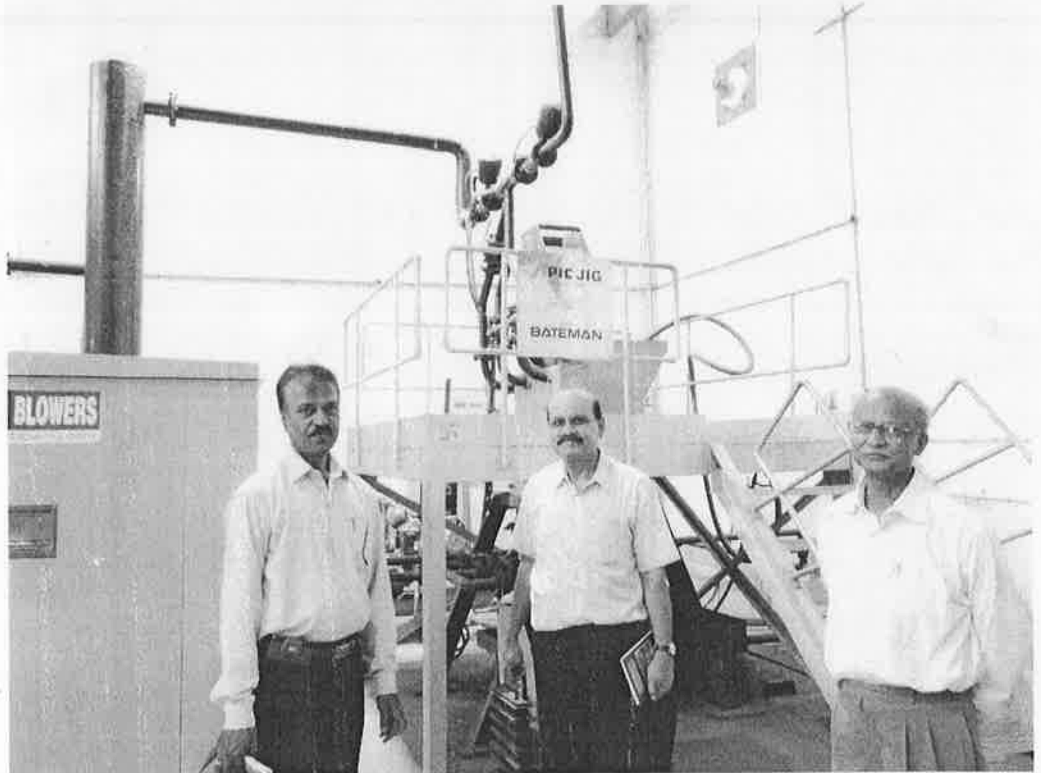


Dr. K.K. Bhattacharya, Chief Scientist NML telling about various types of iron ores

One of the facilities used during the experiments at NML



Process Chart of Quality Improvement of low grade iron at RDCIS



Dr. S.K. Pan, DGM RDCIS and other scientists with one of the equipment used in the experiment