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Research Fund for Coal & Steel

Assessment Report

Research and Innovation

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Directorate-General for Research and Innovation
Directorate G – Industrial Technologies
Unit G.5 – Research Fund for Coal and Steel

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Assessment Report of the
Research Programme for the

Research Fund for Coal & Steel

Directorate-General for Research and Innovation
Research Fund for Coal & Steel

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This document constitutes the Assessment Report of the Research Fund for Coal and Steel (RFCS) Programme covering the period 2003-2010, as requested in the Article 38 of the actual legal basis of the RFCS (Council Decision n°2008/376/EC). As stipulated there and on proposal of the Coal and Steel Advisory Groups, the Commission has appointed an Expert Committee (ExCo) of highly qualified experts of the Coal and Steel sectors to assist in the Monitoring and Assessment exercise. Members of the ExCo are:

Prof Dr Rob Boom	Delft University of Technology / The Netherlands
Dr Jean-Claude Charbonnier	Consultant, Paris / France
Dr Jürgen Czwalinna	Evonik Industries AG, Marl / Germany
Prof Dr.-Ing. Christoph Dauber	TFH Georg Agricola, Bochum / Germany
Dr José-Luis Fuentes-Cantillana	Aitemin Centro Tecnológico, Madrid/Spain
Dr Nikolaos Koukouzas	CERTH Centre for Research and Technology Hellas, Athens / Greece
Mr Bertrand de Lamberterie	ESTEP European Steel Technology Platform, Brussels / Belgium
Dr Jürgen Stahl	HS-Betriebsberatung, Düsseldorf/Germany
Dr Jean-Marc Steiler	JMS Consult, Marly / France
Prof Dr-Ing.Carl-Dieter Wuppermann	cdwuppermann innovation & strategy CDWIS, Krefeld / Germany; Chairman

The ExCo was supported by European Commission staff of the RFCS Unit including Alan Haigh, Head of Unit for RFCS, Monica Spinu and administrative support from Pablo Diaz Bellas and Magda Szaszkiewicz, Ina Vandooren and Radostina Petrova Kirilova.

Additional experts have been specifically appointed as Rapporteurs for assessing in-depth the projects selected in the Technical Groups (TG): Prof. Pär Jönsson (TGS2), Prof.-em. Torsten Ericsson (TGS6), Bernard Bramaud-Gattau (TGS7), Lucien Weber (TGS8), Gerard Tourscher (TGS9).

The analysis has been conducted by the TG rapporteurs and the ExCo members from January 2012 to May 2012. Main rapporteurs for the Assessment exercise are Jean-Marc Steiler, and Christoph Dauber and Nikolaos Koukouzas for the Coal projects.

Acknowledgements

The rapporteurs and the ExCo wish to express their deep appreciation to all those who have contributed to the assessment exercise by their valuable expertise, their comments and discussions. Special thanks is given to the chairmen and all members of the Technical Groups in the Coal and Steel sectors, and to the coordinators of the projects selected for deeper analysis. Their strong commitment has allowed substantiating the great benefit gained from the projects of the RFCS programme.

Contents

Executive Summary

The 2012 RFCS Assessment exercise, based on the legal basis of the RFCS programme, was carried out by an Expert Committee comprising 10 experts (4 for Coal and 6 for Steel) appointed by the European Commission, from nomination by the Advisory Groups. It involved a detailed analysis of the 198 projects completed during the period 2003-2010, covering the Coal and Steel sectors.

After consultation of the members and chairmen of the twelve Technical Groups (TG), a global screening of all projects was carried out by the TG Rapporteurs, experts in the domain of each TG. This analysis delivered an overview of the outcomes of the projects during the period under review.

In the responsibility of the TG Rapporteurs, 46 projects were selected for an in-depth assessment, focused on the benefits for the beneficiaries, the sectors Coal and Steel and Society. It was carried out by exchanges, including visits, with the projects coordinators and main partners, with the help of a comprehensive questionnaire.

The most important benefit of the projects lies in the development of new knowledge, which is quoted as excellent or good, and which can be directly used inside the plants and sectors, as well as in Society.

In both sectors, Coal and Steel, the financial returns, expressed through the criteria cost reduction or economic impact, are rated as the next important benefit. It is considered that the efforts and money – Community money and Industry money – invested in the RFCS Research projects produce operational results that effectively contribute to the economic sustainability of the sectors.

In both sectors again, the development of new processes, new solutions and new products is rated at a similar level as compared to the economic benefits. The RFCS projects have a significant impact on the development of Innovation and its deployment in industrial practice for the beneficiaries and the sectors.

In the Coal sector, progress on the environmental issues and on safety and health are considered as significant benefits. Several projects are especially dedicated to those subjects, namely safety in underground mining or the development of techniques for the use of coal for clean energy production.

In the Steel sector, the projects devoted to process improvement provide significant benefits in terms of quality mastering as well as working conditions. The development of automation, intelligent measuring devices and remote control tools is important for improving the working conditions in a harsh and critical environment. The RFCS projects have provided numerous solutions for decreasing the environmental footprint of the processes, by direct action on the process itself or by proposing end-of-pipe solutions.

Regarding the utilisation of steel, the projects are directly geared with the customers. They have significantly contributed to develop new products, directly aligned with the customer's needs, and consequently to generate new market shares. Numerous examples are found in the automotive market (as Advanced High Strength Steels) and in the building and construction markets. The projects have contributed to maintain or strengthen the position of steel, in strong competition with other materials, like aluminium, composites, polymers, concrete or wood.

Concerning the benefits for Society, beside the increase of knowledge, the RFCS projects have allowed to maintain and even enhance the competitiveness of Europe in the present challenging world market. In addition the RFCS programme provided significant solutions for the global mastering of the environmental footprint of the Coal and Steel industry and for using Coal and Steel in an environment friendly way, for the wellness and benefit of the European citizens. It contributes to maintain the competitiveness and sustainability of the European industry, more than just Coal and Steel.

A detailed analysis of the quantitative benefits of the RFCS projects is presented for some key projects. The financial returns (cost reduction, financial benefit, energy and raw materials savings, productivity increase, and new market shares) were identified and quantified at the level of the beneficiaries. Environmental benefit, impact on health, safety and working conditions were established. The acquisition of new knowledge, including advanced modelling, was described. The results of developing innovative measurement devices were quantified, as well as the promotion of the use of coal and steel.

Out of the 46 selected projects for in-depth assessment, a group of 23 projects has been identified as providing direct and non-ambiguous financial benefits.

At the level of beneficiaries, the RFCS projects have provided significant financial returns. Considering only the 23 projects identified as providing the most straightforward quantitative benefits, the annual financial return was evaluated by the coordinators at about 103 M€/y. This amount can be compared to the budget of those 23 projects i.e. approximately 53 M€.

From the concrete facts and figures provided by the projects coordinators, there were made some estimations of the global benefit for the sectors, based on the likelihood of dissemination and implementation of the projects results all over the sectors. The multiplier for the extrapolation relies on a reasonable and conservative estimation of the number of plants, mines or tonnages which could effectively take benefit from the projects.

According to these assumptions, the overall annual potential benefit for the Coal and Steel Sectors for the selected 23 projects amounts at roughly 700 M€/y.

Cost reduction, including energy and raw materials savings, productivity increase, and development of new market shares are the major components of this benefit.

To capture these potential benefits, it is obvious that additional efforts and budget must be spent at the company level for implementing the relevant technological solutions provided by the RFCS projects.

1. General frame of the RFCS programme

1.1 Objectives

The legal basis of the Research Programme of the Research Fund for Coal and Steel (RFCS) currently operating is outlined in the Council Decision n° 2008/376/EC of 29 April 2008, published in the Official Journal of 20 May 2008 ref. OJ L 130/7, laying down the multi-annual technical guidelines for this programme.

The Research Programme shall support the competitiveness of the Community sectors related to the coal and steel industry. This includes the general aim of contributing to sustainable development, clean and safe production, protection of the environment, conservation of resources, health and safety aspects as well as improvement of working conditions.

The objectives assigned to the RFCS programme are listed below:

Research objectives for Coal

- **Improving the competitive position of community coal,** with special emphasis on reducing the total cost of mining production and the use of coal, and improving the quality of coal.
- **Health and safety in mines,** with special emphasis on improving underground working conditions, occupational health and safety and environmental conditions.
- **Efficient protection of the environment and improvement of the use of coal as clean energy source,** with special emphasis on minimising the impact of mining operation and using of coal on the atmosphere and water within the framework of an integrated management strategy addressing pollution issues: greenhouse gas emissions, capture and storage of CO_2, waste management and water treatment.
- **Management of external dependence on energy supply,** with special emphasis on the definition of strategies for long-term energy supply and the test of innovative techniques for upgrading the Community coal resources.

Research objectives for Steel

- **New and improved steelmaking and finishing techniques,** with special emphasis on enhancing product quality, increasing productivity, reducing emissions, energy consumption and environmental impact and improving the use of raw materials.
- **RTD and the utilisation of steel,** with special emphasis on meeting the future requirements of the steel users and creating new market opportunities for steel.
- **Conservation of resources and improvement of working conditions,** with special emphasis on the conservation of resources in steel production and steel utilisation, the preservation of the ecosystem and the improvement of health, safety , working conditions and ergonomics.

1.2 Structure and Management of the RFCS programme

The dedicated RFCS unit of the Commission manages the Programme with the assistance of several high-level Groups of experts:

- The Coal and Steel Committee (COSCO) composed of representatives of all Member States meets once a year. Its role is to assist the Commission in the overall Programme management.
- The Coal Advisory Group (CAG) and the Steel Advisory Group (SAG). The size and the structure of these bodies are fixed in the legal basis. The members come from both industrial producers and users, Research Centres and Universities. They serve in a personal capacity to assist the Commission in the Programme management. CAG and SAG meet once a year.
- Twelve Technical Groups (TG) monitor the ongoing projects, evaluate the project results and give support to the Commission and to the Advisory Groups as regards the monitoring of the ongoing projects and the content of annual priority setting. Members are experienced experts in the respective sector. There are 3 Technical Groups for Coal (TGC) and 9 for Steel (TGS) responsible for well defined research fields within their sectors. They review project reports, and in particular the mid-term technical implementation reports and the final reports, and meet once a year.

Every year approximately 55 M€ are dedicated to fund Coal and Steel research projects. The budget shares for coal and steel, respectively about 27 % and 73 % reflect the total financial contributions of each sector.

The RFCS programme supports several types of actions: research projects, pilot projects (implementation and operation of a pilot installation), demonstration projects (implementation and operation of a specific installation at industrial scale) and accompanying measures for the dissemination and promotion of the knowledge acquired during the projects.

2. Methodology of the Assessment exercise

2.1 Background

The current Assessment exercise is based on the legal basis of the RFCS Programme whose article 38 prescribes that the Research Programme shall be subject to an assessment exercise on completion of the projects financed during every period of seven years. The benefits of the Research and Technology Development (RTD) to Society and to the relevant sectors shall also be assessed. The assessment report shall be published.

This assessment is carried out in parallel with a monitoring exercise of the Research Programme [1].

It can be recalled that the European Coal and Steel Community (ECSC) Research Programme for Steel had been subjected to an evaluation and assessment, leading to a detailed Report published in 1994 [2].

2.2 Scope and Objectives

The scope of the exercise is to assess the individual projects of the Research Programme which were completed between 2003 and 2010 and for which the Final Publishable Report has been accepted by the Commission Services. The assessment encompasses all aspects of the operation and results of the individual projects.

The functioning of the Research Programme as such, including in how far the programme objectives are achieved, is covered by the Monitoring exercise running in parallel [1].

The objectives of the Assessment exercise are detailed in the Terms of Reference (ToR) for the assessment.

The major focus is on the following aspects:

- Achievement of the project objectives (scientific, technical and economic success)
- Analysis of the benefits provided to the beneficiaries, the sector and Society
- Quantitative evaluation of the benefits generated to the relevant sector (if possible)
- Extent of industrial exploitation of the project results
- Extent of dissemination of the project results in the industrial sector, in academia, and in Society.

2.3 Assessment methodology

According to the Terms of Reference for Assessment, the assessment has involved two steps:

- Consultation of each Technical Group (TG) to screen out all completed projects in their domain. The experts were requested to give their instant views about the outcomes of all projects in their field of expertise. For that purpose, a short questionnaire, covering also some Monitoring aspects, has been established and circulated among the TG's. In addition, all TG Rapporteurs were given a time slot in the 2011 TG meetings, in order to explain the approach and to collect some feed-back from the experts (see Chapter 3).
- Deep assessment of a sample of selected projects by evaluation of reports, site visits and interviews with the project coordinators, selected beneficiaries and other stakeholders (see Chapter 5). A full questionnaire, focusing on the evaluation of the

benefits has been used as a guide line for the interviews.

In total 198 projects have been completed, with a Final Report approved, during the period of evaluation 2003-2010 covered by the Monitoring and Assessment exercise. The assessment has been carried out by experts (ExCo members and specially appointed experts) acting as Rapporteur for each TG (Table 1).

TG	Topic	Total projects	Projects for deep assessment	Rapporteur
TGC1	Coal mining operation, mine infrastructure & management, unconventional use of coal deposits	9	2	Christoph Dauber
TGC2	Coal preparation, conversion and upgrading	7	2	Christoph Dauber
TGC3	Coal combustion, clean and efficient coal technologies, CO_2 capture	16	5	Nikolaos Koukouzas
TGS1	Ore agglomeration and Ironmaking	7	2	Jean-Marc Steiler
TGS2	Steelmaking processes	14	3	Pär Jönsson
TGS3	Casting, reheating and direct rolling	18	4	Bertrand de Lamberterie
TGS4	Hot and cold rolling processes	15	3	Jean-Claude Charbonnier
TGS5	Finishing and coating	14	4	Jean-Claude Charbonnier
TGS6	Physical metallurgy and design of new generic steel grades	20	5	Torsten Ericsson
TGS7	Steel products and applications for automobiles, packaging and appliances	16	3	Bernard Bramaud-Gattau
TGS8	Steel products and applications for building, construction and industry	38	8	Lucien Weber
TGS9	Factory-wide control, social and environmental issues	24	5	Gérard Tourscher
	Total	**198**	**46**	

Table 1. RFCS Technical Groups (TG), number of projects and Rapporteurs

In a first phase, according to their expertise, the TG Rapporteurs have identified, amongst the 198 projects, a set of 78 ones they considered as the most significant and promising regarding the assessment of benefits (Figure 1). In a second phase, a final sample of 46 projects has been selected for deeper assessment, with due consideration to the selection rules initially defined to ensure the representativity of the Assessment. In the selection process, particular attention has been paid to the following criteria: coverage of Technical Groups, budget, kind of activity, consortium size and composition.

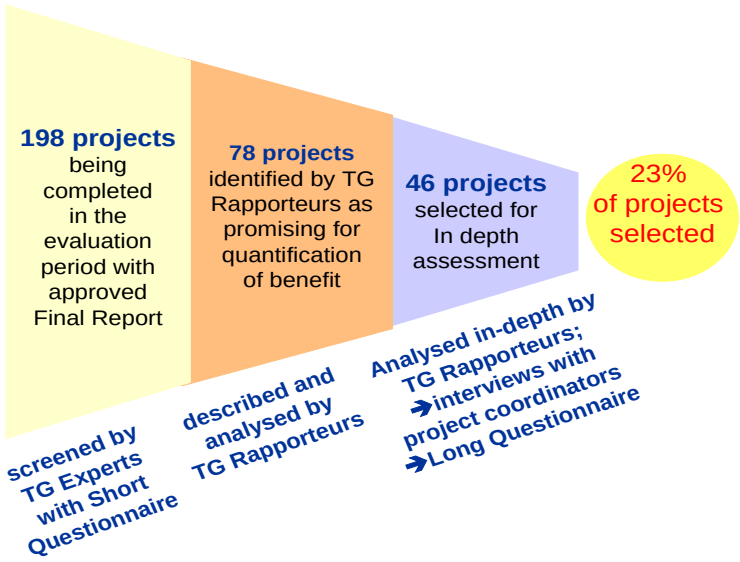

Figure 1. Selection process of projects for in-depth assessment

Budget wise, the sampling of projects for deep analysis is fully representative of the respective weight of the coal projects and steel projects in the whole RFCS programme covered by the Monitoring and Assessment exercise (Table 2): coal projects account for 25.3 % of the total budget covered by the exercise, whereas the share is 26.0 % in the sample selected for deep assessment. The sampling ratio of projects in the selection is 23.2 % with reference to the number of projects and 26.6 % with reference to the budget involved. The latter ratio is very similar for Coal and Steel, and ensures the statistical validity of the assessment results.

	Coal sector		Steel sector		Total Coal & Steel	
		Selection ratio		Selection ratio		Selection ratio
Number of projects covered by the M&A exercise	32	100 %	166	100 %	198	100 %
ratio coal, steel	*16 %*		*84 %*		*100 %*	
Number of projects selected for deep assessment	9	28.1 %	37	22.3 %	46	23.2 %
ratio coal, steel	*19.6 %*		*80.4 %*		*100 %*	
Budget of projects in the M&A exercise (M€)	78.033	100 %	230.116	100 %	308.149	100 %
ratio coal, steel	*25.3 %*		*74.6 %*		*100 %*	
Budget of projects selected for deep assessment (M€)	21.339	27.3 %	60.706	26.4 %	82.045	26.6 %
ratio coal, steel	*26.0 %*		*74.0 %*		*100 %*	

Table 2. Representativity of the sample of selected projects

3. Screening of all projects

The global analysis carried out for all projects is based on the following criteria: success of the projects, exploitation of the results and benefit gained at the level of beneficiaries, sectors and Society. At this stage, the screening only reflects the instant perception of the consulted TG experts, without deep analysis of the projects. This may explain the relatively high number of "No Answer" for some questions, due to possible lack of information.

3.1 Achievements of individual projects objectives

In Figure 2 the results of the projects screening are illustrated in terms of scores of the achievement of the project objectives. Overall, both scientific and technical success is very high as a large number of projects, around 80 %, receive a score equal or over "80 % of success rate". The projects are also successful from economic and social point of view but with lower quotes: nearly 60 % of projects are successful at 60 % or more for economic and a bit less for social. Even if the social issues are not among the prime objectives of the projects, nevertheless, social benefits for Society are registered, as detailed in the deep analysis of the projects (§ 5.4).

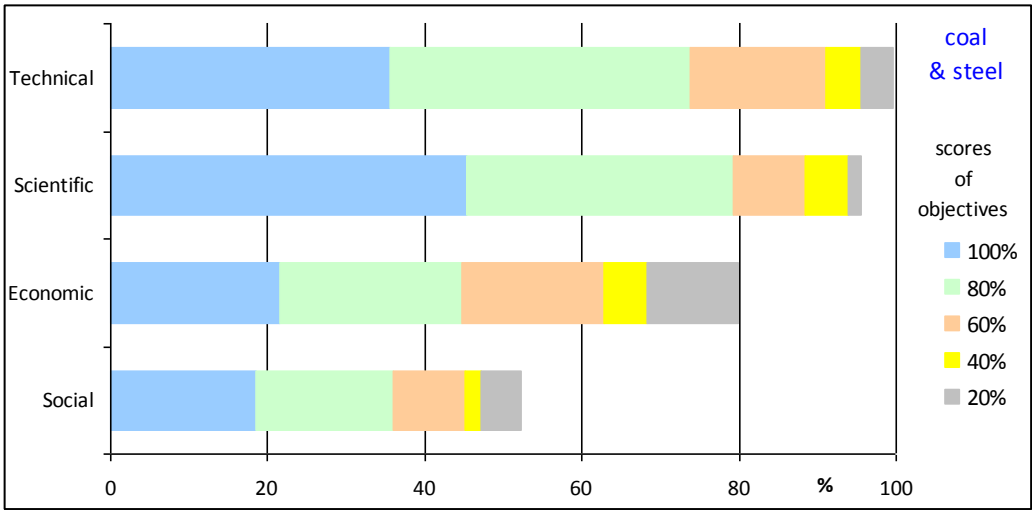

Figure 2. TG experts views about the achievement of individual objectives of the Coal & Steel projects

(complement to 100 % represents "No Answer" or not relevant)

Comment:
Globally, the RFCS projects are rated as very successful, which reflects the general relevance of the projects as well as the quality of their management.

3.2 Exploitation of the projects results

The degree of exploitation of the results is high in the project itself and in similar applications in the company conducting the project: about 90 % of projects exhibit a high or medium degree of exploitation at the beneficiaries level (Figure 3).

Concerning the sector or the scientific community, the degree of exploitation is with an average of 80 %, smaller but still very significant, especially in the Steel sector.

The degree of exploitation decreases at the level of Society (20 % of projects rated high + medium). In fact this is not much surprising as the projects are very specialised and dedicated to specific sectors. Moreover, the effects in Society are not always directly visible, and their identification requires a deeper assessment. This aspect will be addressed in a more relevant way in the deep assessment chapter (§ 5.4).

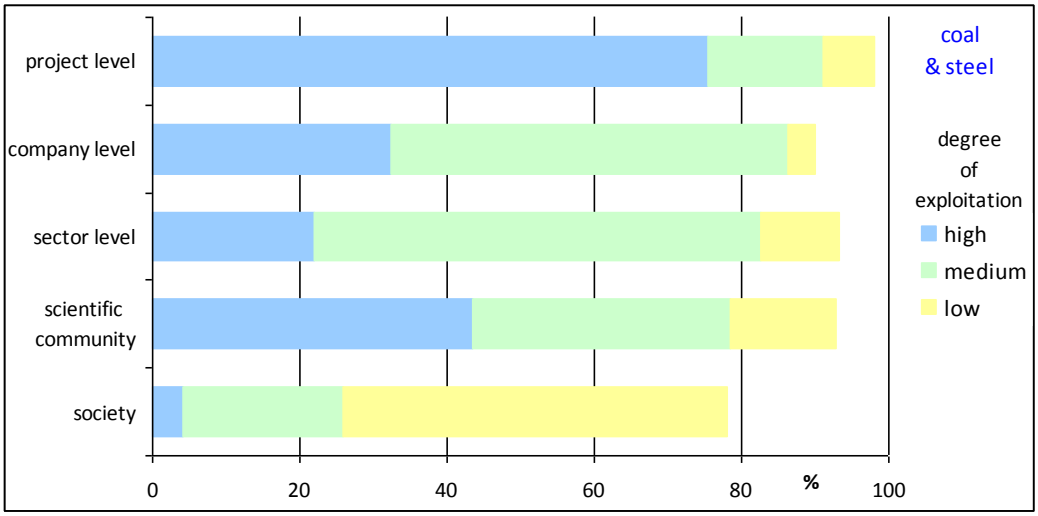

Figure 3. TG experts views about the exploitation of the results of the Coal & Steel projects (complement to 100 % represents "No Answer" or not relevant)

Comment:
The quick and full exploitation of the research results is the core of each innovation process. This is of special importance for focused research projects, as it is the case for RFCS. Exploitation should not only happen at the level of the project beneficiaries, which is quite natural, but also at the level of the sector or if relevant Society, in order to contribute to the competitiveness and sustainability of the European industry.

3.3 Benefit generated by the projects

The benefits generated by the projects have been evaluated by the TG Experts, with reference to a list of about 20 categories of possible benefits suggested in the questionnaire.

At this stage, it must be recalled that this evaluation, which covers all 198 RFCS projects under review, only represents the instantaneous perception of the TG experts, without deep analysis of the projects. A more substantiated evaluation of the benefits, resulting from an in-depth assessment of selected projects, is discussed in Chapters 5 and 6. The Figures 4 to 8 present the proportion of projects having generated a benefit in each category of benefit. The benefits for the beneficiaries and the sector are analysed in a separate way for the Coal and Steel sectors. Only the benefits rated "excellent", "good" and "satisfactory" are represented here. The ratings "poor" and "very poor" are completely marginal in the expert's evaluation: the complement to 100 % corresponds thus to the projects for which the nature of the benefit was not relevant for the project or not known by the experts.

3.3.1 Benefits for the Beneficiaries

According to the Technical Experts, the increase of knowledge by far represents the most important benefit gained from coal as well as steel projects: about 100 % of the projects are considered to contribute, at least satisfactorily, to the increase of knowledge (Figures 4, 5).

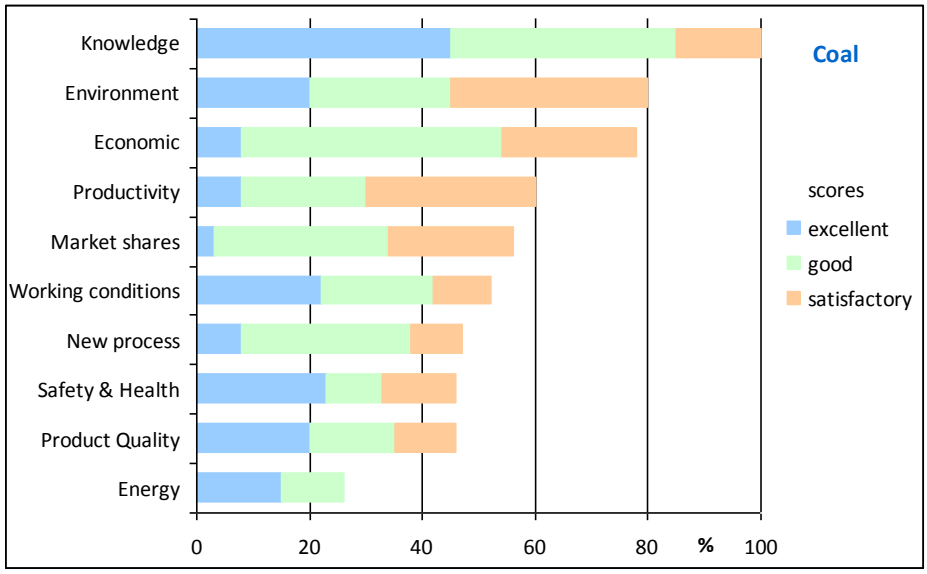

Figure 4. TG experts views about the Benefit perceived for the beneficiaries (coal); % of projects having a significant impact on the criteria (complement to 100 % represents "No Answer" or not relevant)

In the Coal sector, high benefit is also perceived in the fields of economic and environmental effects; the increase of productivity is rated at the 4th rank. Working conditions and health & safety are quoted at a significant level, as 40 to 50 % of the projects have, at least a satisfactory impact. The comparatively lower coverage of some other aspects could be more a result of the lower awareness of these particular aspects than of their actual negative assessment.

In the Steel sector, the most obvious benefit quoted after knowledge, concerns the economic impact of the projects. The developments of new processes, new products and new applications are considered as valuable outcomes for a significant proportion of projects, between 40 and 50 %. A relatively low proportion of steel projects are rated for their direct effect on environmental or energy related issues.

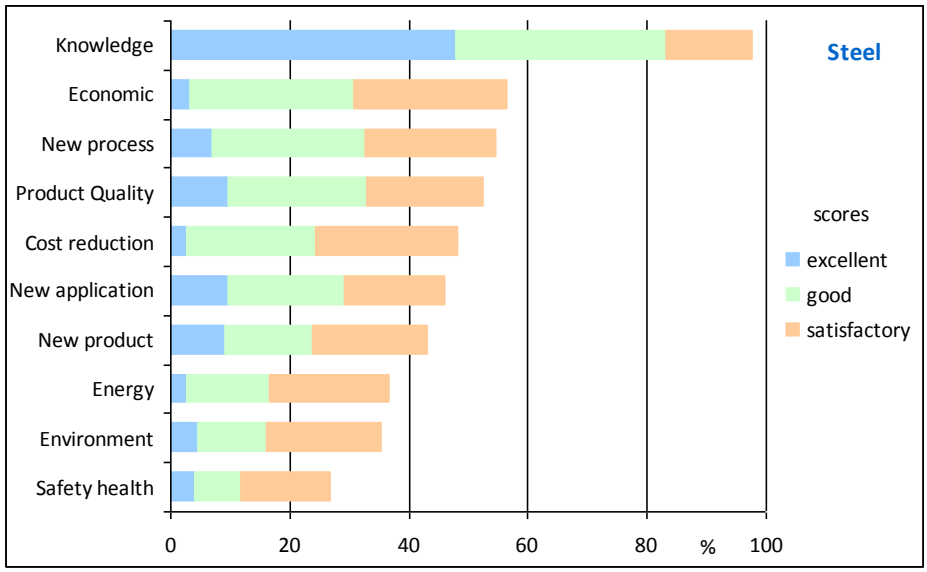

Figure 5. TG experts views about the Benefit perceived for the beneficiaries (steel); % of projects having a significant impact on the criteria (complement to 100 % represents "No Answer" or not relevant)

Comment:
In fact, many steel projects, even if not primarily focused on environment and energy, nevertheless have an indirect impact on those issues, which have a fully through-process and value-in-use character.

This aspect should be considered when setting the RFCS priorities for the steel projects.

3.3.2 Benefits for the Sectors

The general tendency of the benefit analysis for the sector was very similar to the one for the beneficiaries (Figures 6, 7). Knowledge received the highest score for Coal and Steel.

In the Coal area, after knowledge, the benefits for the sector are environment, productivity, and economic aspects, roughly the same order as found for the beneficiaries.

In the Steel area, the benefit of the projects in terms of improvement of steel competitiveness in Europe is quoted in the second rank. This fully complies with the RFCS objectives for steel. The economic impact is rated at the 3rd rank, ahead of the development of market shares for steel. The latter criterion is consistent with the objective of developing new high quality steel products in Europe, to secure the sustainability of the steel industry.

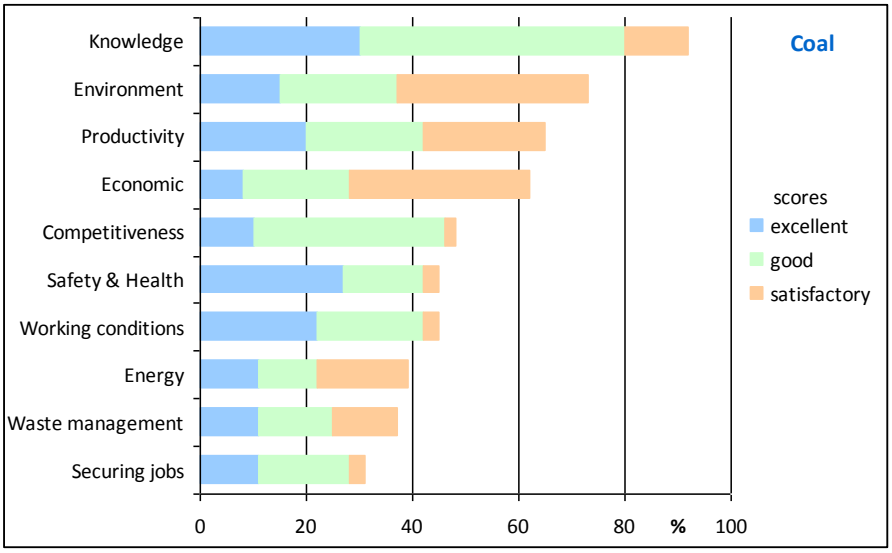

Figure 6. TG experts views about the benefit perceived for the Coal sector; % of projects having a significant impact on the criteria (complement to 100 % represents "No Answer" or not relevant)

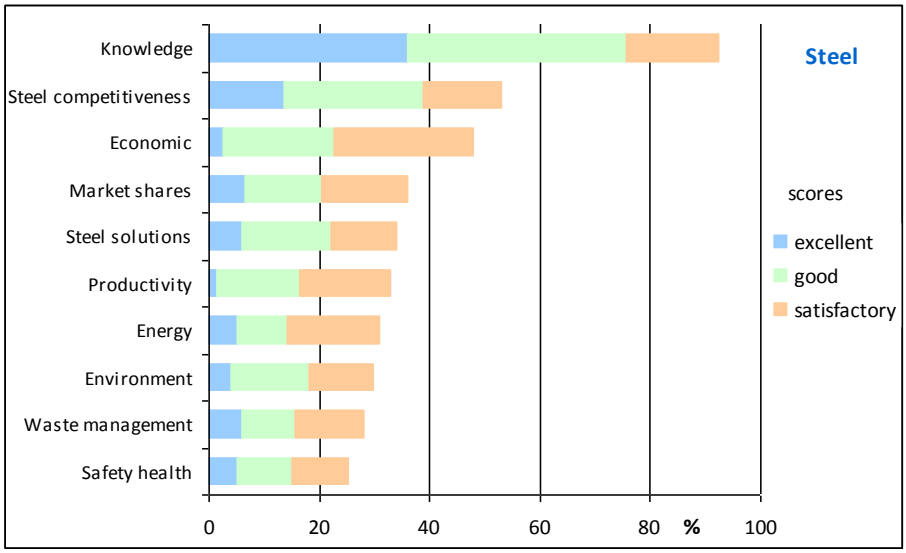

Figure 7. TG experts views about the benefit perceived for the Steel sector; % of projects having a significant impact on the criteria (complement to 100% represents "No Answer" or not relevant)

Comment:
The ranking of the major benefits is very similar at the level of beneficiaries and sector. This reflects a good perception of the dissemination of the projects results in the Coal and Steel sectors.

3.3.3 Benefits for Society

Regarding the benefits for Society, the evaluation of projects is very similar in the Coal and Steel sectors (Figure 8). The major benefit for Society lies in the increase of knowledge. The RFCS programme strongly contributes to sharing this new knowledge within Europe, in a swift and efficient way (see results of Monitoring [1]). The next direct benefit gained from the projects is precisely related to the European competitiveness. The economic impact, the development of new applications and new market shares are quoted at a significant level for about half of the projects.

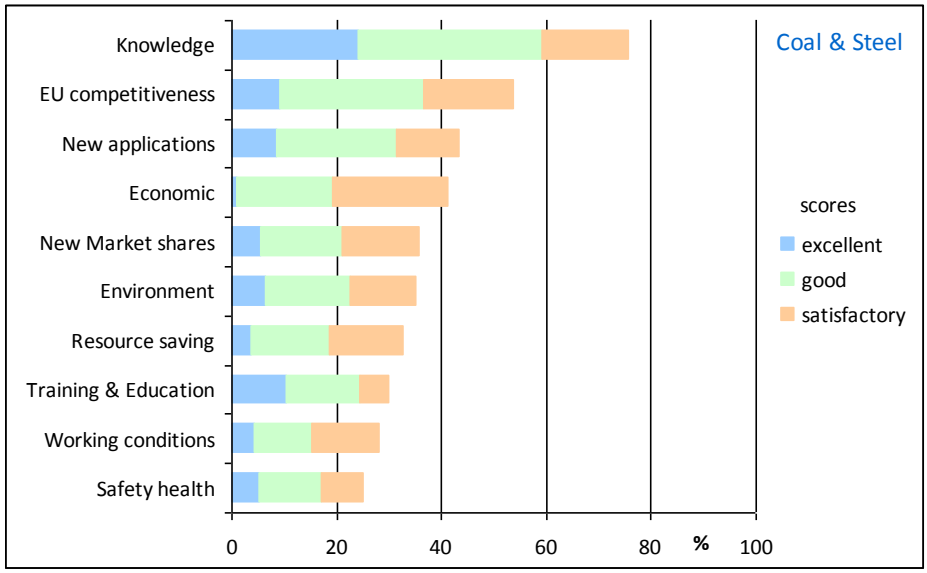

Figure 8. TG experts views about the benefit perceived for Society;
% of projects having a significant impact on the criteria
(complement to 100 % represents "No Answer" or not relevant)

The highly important issues for Europe, concerning environment and resource availability, are also well addressed by the projects. The benefit in training and education, as well as working conditions and safety and health, is quoted at a significant level. Regarding these two last categories of benefits, one can notice the surprisingly high proportion of "no answer" from the TG experts. This can be caused by a lack of information or a possible misunderstanding of the short questionnaire used to collect the answers. As a result of this, there may be an underestimation of the benefits that the RFCS has produced for Society. In particular, some issues such as securing of jobs, fixing of population in remote areas, or creation of spin-off companies to other sectors, have not been mentioned, whereas in the opinion of the members of the Expert Committee there is no doubt that,

either directly or indirectly, these outcomes of the RFCS projects represent a significant contribution to the benefit for Society. A more meaningful evaluation is provided by the in-depth assessment of the projects, presented in § 5.4.

Comment:
The main objective of the RFCS programme is to strengthen European competitiveness. The ranking of the benefits is well in line with needs of the Coal and Steel sectors which contribute to European competitiveness. New knowledge provided by the projects is well managed and made available to the world of education of young people. The projects are also considered as beneficial for the working conditions and safety and health.

4. Outcomes of all projects over the 2003 – 2010 period.

During the period 2003 – 2010 the projects funded under the RFCS Programme have significantly contributed to meet the Research Objectives for Coal and Steel, as defined in the Council Decision of 29 April 2008 (see § 1.1). The most relevant outcomes of the 198 projects under review are presented below, in connexion with the RFCS objectives.

4.1 Outcomes of Projects in the Coal Sector

- **Improving the competitive position of Community coal**

  - *Coal Mining*

Several projects gained to improve productivity and costs by implementing advanced automation and communication technologies in underground coal mines. It started with a project dealing with the fundamentals of this technology and providing the necessary conditions for further applications. These findings have been the input for two succeeding projects, one increasing the efficiency of roadway drivages, a second one developing fully automatic and highly-performing longwall equipment. Particularly the last project was very successful as the fully automated shearer was awarded at the International BAUMA Exhibition 2009 in Munich.

The new developed sensors and IT-applications have also delivered a major input with regards to maintenance issues. Proactive maintenance procedures monitored by a network of sensors and control devices essentially reduce the operational downtime and increase the productivity of faces and headings.

Geotechnical issues and support systems for gate roads have been another topic of the projects. As the mining depth in European coal deposits ranges between 600 and 1400 m., it is a real challenge to keep the gate roads in function. Geotechnical modelling, innovative support systems and monitoring tools have been the very useful outcomes which are nowadays in operational usage and are indispensable pre-requisites for mining at a great depth.

  - *Coal Conversion*

As EU coke makers face rapidly rising cost of high quality coking coal and their restricted availability, the need for an improved flexibility of carbon sources has increased. The use of semi-coking coals, anthracite, petroleum coke, biomass or waste plastics have been tested and evaluated. This research was accompanied by new and improved mathematical models to facilitate coke quality prediction. The project findings offer a potential of economic benefits to the coke makers without affecting environmental issues.

Most coking plants in the European Community were designed for an expected life of 20 to 25 years, but many are now over 30 years old. Due to the global economic development the steel industry took a cautious approach to invest in building new coking plants. The authorizing procedures for new plants are time-consuming and may involve risks and uncertainties. Therefore, it is even more important to prolong the life of the existing coke ovens. RFCS funded projects delivered the mathematical model of the coke oven walls and, even more valuable, the monitoring tools for chamber wall observation, flue control and oven top deflection, which all contribute to the extension of the coke ovens life time.

- *Coal combustion*

Coal combustion, in general terms, was addressed by several projects over the period 2003-2010. More specifically the following technologies were examined: coal combustion, coal gasification, circulating fluidized bed technology, monitoring techniques, gasification technology, co-combustion of coal with biomass, oxy-fuel combustion and CO_2 capture.

Efficiency improvement in coal combustion is considered of high importance and therefore activities related to the improvement of cleaning equipments and heating surfaces for more efficient cleaning systems and processes under demonstration conditions as well as the development of novel burners with higher fuel flexibility capabilities were addressed.

Another field of research that was addressed was Monitoring Technique. Advanced on-line methods for ash deposition as well as on-line process performance calculation methodologies were developed and validated.

The advanced combustion technology of Circulating Fluidized Bed (CFB) was examined in various RFCS coal projects as this is a promising technology for electricity generation which combines increase in efficiency, decrease of emissions, and fuel flexibility. Co-combustion of coal with biomass was also examined with the circulating fluidized bed technology and useful results were obtained for the fuel characterization and the conditions required. The Once Through Supercritical Circulating Fluidized Bed Technology was developed while scale up CFB technology to utility scale was obtained.

Gasification technologies were also developed within RFCS coal projects over the period of 2003-2010. Syngas from gasification of low grade coal and biomass was produced. Rotary kiln gasifier with innovative catalytic gasification was developed. The purification of synthesis gas was also examined.

Regarding the CO_2 Capture which is part of the Carbon Capture and Storage Technologies and is very much related with the future of the Coal sector, the most promising technology is considered Oxy-fuel combustion, which was examined in several research projects under the RFCS Programme. More precisely mathematical modeling and boiler designs as well as oxy-capture technologies were developed in the examined RFCS coal projects.

Most projects were successful from technical, scientific and economic points of view. They improved the existing knowledge on coal combustion and gasification and achieved important results on the boiler performance, power plants efficiency, co-combustion of coal with biomass and wastes, utilization of combustion by-products, and CO_2 capture.

- **Health and Safety in mines**

Even more than in other industries safety is a crucial issue in underground coal mines. As European coal mines have gained an exemplary positive record regarding accidents and fatalities this remarkable success was assisted by RFCS funded projects. High sensitive measuring systems for analysing gas, approved devices in explosive atmosphere, climate control in workings and rescue procedures have been some of the topics. Sophisticated Information and Communication Technology (ICT) applications developed in different projects have been successfully engaged in communication and warning procedures.

Due to the greater depth another severe hazard to European coal mines is outburst of rock and coal associated with methane. Research works aimed for the application of seismic techniques to measure rock-burst activities. Although further improvements are desirable, seismic

monitoring nowadays is state-of-the-art in concerned mines.

As mentioned before, innovative support systems for deep mines and suitable monitoring tools have been developed by RFCS sources. This applies not only to productivity; it is a safety concern, too. The threat of sudden failure of support systems can be eliminated by adequate monitoring tools and modern support systems create safe working conditions in deep mines.

- **Efficient protection of the environment and improvement of the use of coal as a clean energy source**

  - *Protection of water tables*

There is a justified concern that mine water may have a hazardous effect to the environment. Consequently, mine water management, monitoring and control techniques, prediction of aquifer contamination and sealing measures have been the focus of RFCS funded projects. The so called box model proved to be a very appropriate tool in simulating water rise in large coal fields. Equipment and methods for monitoring mine water flows and composition have been successfully tested and applied. And it was very fruitful that the knowledge about mine water flows in different coal fields and countries was focussed in joint projects.

  - *Reduction in emissions and utilization of fly ash*

The reduction in emissions from coal utilization as well as the utilization of fly ash, the by-product of coal combustion, was addressed by several projects over the examined period in the RFCS Programme.

Regarding the reduction of emissions in coal combustion, which is of paramount importance for the Coal sector, several projects were carried out, addressing corrosion, slagging, fouling problems occurring in the boilers, NO_x emissions, and dioxin releases in coal combustion and coal/wastes combustion. The slagging and fouling phenomena are operational problems in the coal boilers which often relates with co-combustion of coal with biomass and wastes. The examination of these problems significantly contributes to the decrease of emissions in the atmosphere. NO_x emissions also make serious problems to the environment and consequently to the Coal sector.

The utilization of fly ash, which results from the combustion of coal to generate electricity, is also of high importance for the Coal sector as it creates serious environmental problems from the deposition of fly ash in the field nearby the power station or in the open-cast mine. Fly ash from different origins (coal, biomass and wastes) was examined. In addition use of fly ash for geopolymerization was carried out.

The coal projects improved the existing knowledge on the emissions reductions and the utilization of combustion by-products.

  - *Environmentally-friendly products*

Despite the fact that coal as a primary energy resource has a limited potential for product improvements, a beneficial niche application should be mentioned. The steel and aluminium industries rely on coal-tar pitches which are used for the preparation of cathode blocks and graphite electrodes. To reduce the environmental impact derived from these pitches anthracene oil which is a byproduct in the coking process has been tested. The outcomes of the project revealed that anthracene oil based pitches are characterized by high purity and a low content in genotoxic compounds. Additionally, the project proved the excellent capacity of anthracene oil derivates to produce advanced carbon materials.

- **Management of external dependence on energy supply**

As in Europe the energy supply is threatened by a dependence on imported oil and gas, an accompanying measures project aimed to promote and disseminate information about coal to liquids activities, especially in Central and Eastern Europe. Another research activity has dealt with the upgrading of high moisture, low rank brown coals to hydrogen and methane. A technical and economic process assessment proved that the C2H-process is economically competitive compared with conventional systems, especially for CO_2-capture.

The RFCS funded activities concerning unconventional usage of coal deposits have been intensified in the last three years. Some ongoing projects should be mentioned, for example the investigation of adsorption and swelling behaviour of coal to determine the feasibility of CO_2 sequestration and CH_4 production enhancement. Another research project deals with deep underground coal gasification and the permanent storage of CO_2 in the distinct areas. And the CARBOLAB activities will improve the knowledge about carbon storage and coal bed methane production as "in situ" underground tests will be executed in this project.

4.2 Outcomes of Projects in the Steel Sector

- **New and Improved Steelmaking and Finishing Techniques**

In the upstream part of the steel manufacturing route, major improvements were made on the productivity and flexibility of the process, leading finally to cost reduction. These improvements have been made possible by a fruitful coupling between new knowledge, new measurement tools and techniques, supported by extensive modelling work. Several examples can be mentioned in different domains: productivity increase by 2 % of the refining process in the steel converter by means of an innovative on-line determination of steel-melt temperature; improved process strategies, helped by new instrumentation, to avoid oxide clogging at continuous casting; design of new work roll cooling systems in the hot strip mill, to reduce the wear and extend the life time of the rolls; increase of productivity around 5 % at the pickling line, thanks to new on-line sensors for the detection of over-pickling and under-pickling.

The upstream domain represents a strong issue, regarding environment and emissions. Several projects have allowed establishing a comprehensive understanding of the mechanisms of CO, SO_x, NO_x, and organic compounds emissions. New process rules have been investigated and proposed to optimise the process while complying with the environmental constraints. Significant examples can be mentioned for the NO_x reduction in the iron ores sintering process or in the reheating furnaces. This new knowledge helps the European Steel Industry to select in a realistic way any new investment for end-of-pipe treatment of emissions.

In connection with the ULCOS project, which aims at drastic decrease of CO_2 emissions by major technology changes in the medium-long term, different projects have provided short term customised and low cost solutions to reduce the CO_2 emissions. In one scenario it appears possible to reduce the CO_2 emissions of the ironmaking process by 9 %, without any extra cost or negative impact of the blast furnace productivity.

The energy consumption is a major issue, especially in the upstream part. New burner technologies have been proven to allow a significant reduction of energy needs, for example 20 % reduction for the steel ladle heating. Intelligent diagnosis and control

systems for slab reheating furnaces have brought about energy saving around 3 %.

In the downstream part of the production route, in addition to productivity, the quality of the intermediate product is a key issue, as it has a direct impact on the operating cost, on the delivery time and on the quality of the final product supplied to the customer. Most of the improvements have relied on the development and use of new measuring devices, allowing to monitor on-line the quality (internal and surface quality, shape, dimensions, surface micro-geometry, microstructure) of semi-products (slabs, strips, blooms, billets), to detect as early as possible non-quality problems and to launch countermeasures to recover the aimed quality. This is of particular importance for the Advanced High Strength Steels (AHSS), which may be more sensitive to quality issues.

Several examples are to be mentioned: optimisation of the cooling strategy at continuous casting to reduce the crack occurrence in billets of micro-alloyed steels; hydrogen sensor to detect over-pickling and control the surface roughness; development of an innovative sensor to measure on-line the waviness of the strip, which is a major issue for the final product delivered to customer; fast measurement of organic coating thickness (5-30 µm) on coil-coated products. In addition, several studies have allowed to define the process for controlling the surface reactivity of AHSS, and improving the quality of the galvanised products. New coating technologies have been developed and implemented, to meet the customer's requirements: improved corrosion resistance using Zn-Mg coating and new curing technologies for organic coating, opening new markets for the steel products.

Regarding the assessment of surface quality, thanks to a series of ECSC and RFCS projects, the European Steel Industry has always been at the leading edge for the automatic inspection of surface of steel. Different systems have been developed in Europe and widely commercialised worldwide. The most recent projects have allowed to drastically improve the detection performance and the rapidity of the systems, opening new doors for on-line control. This has resulted in a more thorough use of such systems for monitoring the product all along the line, from hot strip mill to the finishing lines.

- **Utilisation of Steel**

The relevant projects aimed at increasing the use of steel, through improvement of the final properties of existing steels or development of new steel grades for the most demanding customer applications.

Several projects were undertaken to increase the basic metallurgical knowledge, especially the complex relationships between steel microstructure, metallurgical properties (strength, forming properties, fatigue and corrosion resistance) and process conditions. This gives the basis for optimising the existing grades and developing new advanced steel grades, like multi phase steels with complex microstructures.

In the case of steels for the automotive market, the major concern is still about lightweight steel solutions. This objective directly results from the need to meet the automotive industry challenge of reducing the CO_2 emissions of the cars, aimed at 90 g_{CO2}/km, all over Europe. Several projects were addressing this issue: significant results have been obtained in this domain, with the optimum design of new high strength-high formability steels (DP, TRIP, TWIP grades).

In addition, easier stamping of some new grades allows now to achieve more

complex steel parts, reducing thus the number of parts in the car body.

New surface technologies have been developed for highly functional materials, which also increase the durability of automotive products. Therefore these steels represent a leap forward and a credible alternative to the use of aluminium in the car body, and they have created new market opportunities in Europe. The comprehensive metallurgical knowledge gained in the frame of the projects, along with the extensive use of numerical models, have drastically improved the design and the development time of new steel grades and steel parts, which helps in developing fruitful partnerships with the steel users and car manufacturers, and contributes to the sustainability of the Steel sector. The optimisation of the fabrication process of those steels, e.g. high manganese grades, has been addressed in several complementary projects: defining a robust and economic process window for the new steel grades is indeed a prerequisite for their market development.

The major issues addressed by the projects for the construction market were dealing with the safety of structural elements with regard to resistance to fire and earthquakes. New knowledge has been acquired in the field of design of structural elements (for short span bridges, low rise buildings, industrial halls), and in the field of in-use properties of steel (welding, joining with other materials). This has contributed to increase the penetration of steel in the construction market, at the expenses of other materials like concrete and wood. Especially noteworthy in the domain of construction, is the fact that several accompanying measures type projects have been carried out in order to prolong the R&D findings by design guidance tools and recommendations to support architects, regulators, and engineers with the practical application of steel. In this respect, several Eurocodes have been updated and developed as well. In the field of fire resistance, the new concept of Natural Fire has been developed and promoted in Europe as a credible alternative to the ISO approach, which is known to be unfavourable to steel.

Even if not directly, most of the projects dealing with the utilisation of steel clearly address the environmental impact. In both automotive and construction markets, steel heavily contributes to reduce the environmental load in the society, which should contribute to the image of steel as a green material.

- **Conservation of resources and improvement of working conditions.**

The better prediction of semi-product and product quality, thanks to the use of advanced models and sensors, which is a common objective of many projects, has brought about a significant economic benefit that merely lies in the yield improvement and the reduction of the rectification cost along the manufacturing route. The generalisation of the concept "first time right" has clearly a direct impact on the conservation of resources and energy.

The increasing use of advanced high strength steels in the automotive industry in Europe has contributed to the weight reduction of cars, leading to a significant decrease of the fuel consumption during the whole life of the car. There is a clear positive impact on the conservation of resources.

Improvement of health and safety was an underlying benefit of several projects in the field of process as well as product development. New on-line sensors, supplemented with models, have allowed developing remote working places, avoiding the presence of workers in the most harsh conditions (e.g. blast furnace casthouse, continuous casting floor, vicinity of hot

travelling product in rolling mill, close to liquid zinc pot in the galvanising plant, working conditions in the pickling lines, etc).

In addition, automation and advanced monitoring tools contributed to release the workers from repetitive and tedious tasks, leading to an enrichment of the content of their job while introducing the knowledge management concepts.

5 In – Depth Assessment of the Selected Projects

5.1 Methodology

The representative sample of 46 projects, selected out of the list of 198, has been subjected to a deep assessment, merely dedicated to the evaluation of the benefits for the beneficiaries, the sectors and Society (Table 3a, 3b). The assessment work has been carried out from January 2012 to May 2012 by the TG Rapporteurs, via interactive exchanges and interviews with the project coordinators and the main industrial beneficiaries of the projects. In most cases, it has involved a visit to the coordinator and a face to face discussion. A detailed questionnaire had been sent in advance to the coordinator, as a guide line for the discussion. A short description of each selected project is given in Annex A.

For each category of benefits (for the beneficiaries, the Sector, Society), a series of 20 key indicators has been proposed to classify the benefits perceived from the projects. These indicators, which appear in Figures 11 to 14 (y axis), explicitly refer to the RFCS objectives. In addition to the qualitative benefits, it has been requested from the project coordinators and beneficiaries to assess, if possible, the quantitative benefits as well. Those benefits can be expressed according to technical indicators or, in some cases, as financial returns.

All project coordinators received very positively the assessment request and answered in a highly professional way, although they have had some difficulties in cases where it was necessary to dig out information from several years in the past.

TG	Project Acronym	Project Title	Budget (k€)
TGC1	NEMAEQ	New mechanisation & automation of longwall and drivage equipment	3 809.157
	MONSUPPORT	Development of more economical innovative support systems for gate roads under the influence of rock stresses	2 882.817
TGC2	ECOPITCH	Development of a new generation of coal-derived environmentally-friendly pitches	2 015.084
	IMPECABL	Improving environmental control and battery life through integrated monitoring systems	1 479.333
TGC3	OXYMOD	Development & experimental validation of a math. modelling methods for oxy-fuel combustion for CO_2 capture in large power plants	2 156.685
	FLOX-COAL	Development of a pilot-scale flameless oxidation burner for ultra low NO_x combustion of pulverised coal	2 996.203
	LIGPOWER	More efficient cleaning concepts for stepping up availability of lignite-fired power plants	2 312.896
	CFB800	Utility scale for competitive coal power	3 396.235
	CCTPROM	Clean coal technology R, D&D promotion and dissemination	290.353
Total Budget of selected projects in the Coal sector			21 338.763

Table 3a. List of Coal projects selected for deep assessment

TG	Project Acronym	Project Title	Budget (k€)
TGS1	ENHANCED BF	Enhanced blast furnace operation and service life by improved monitoring and control of the hearth and blast furnace uniformity	2 315.055
	SHOCOM	Short term CO_2 mitigation for steelmaking	2 402.677
TGS2	DOT APPLICATION	Application of direct optical temperature measurement in steelmaking process	789.975
	IMSTEELAD	Investigations & measures to reduce emissions and energy consumption during preheating of steel ladles	1 775.447
	PROMS plus PROMS/EAF	Cost efficient metallurgy for production of novel ultra high strength deep drawable steel grades with high Mn from 10 to 25% (+ EAF)	1 587.258
TGS3	FLUXFLOW	Enhanced steel product quality & productivity by improved flux performance in the mould through optimising the multiphase flow conditions	1 770.935
	CLOGGING	New strategies for clogging prevention for improved productivity and steel quality	1 858.335
	SLAGFILMOWL	Optimising slag film properties and determination of operational window for lubrication, mould heat transfer and shell formation	2 046.240
	SMARTFIRE	Real-time intelligent diagnostics and optimisation of reheating furnace performance	2 056.119
TGS4	ROLLMARK	Roll mark detection on the tandem mill	1 515.830
	EWRCOOL	Effective work roll cooling	1 906.889
	ASYMROLL	Using asymmetrical rolling for increased production and improved properties	1 592.905
TGS5	HIGHPICK	Optimised productivity and quality of pickling by on-line control of pickling surface	1 652.096
	CARSTEEL	Characterizing the surface waviness of hot dip galvanized steel sheets for optical high quality painting	1 435.539
	WAVIMETER	Development of waviness measurement of coated products	1 556.741
	NOVANNEAL	Novel annealing procedures for improving hot dip galvanizing of high strength steels	1 566.642
TGS6	CARBAIN	New ecological and low-cost answers to end user demands on high performance steel components	1 563.708
	CORINOX	Avoiding catastrophic failure of stainless steels	1 280.666
	MEPMO	Mechanical property models for high strength complex microstructures	1 634.073
	MICROQUANT	Microstructural quantification of multiphase steels	2 340.492
	ACTRESS	Austenite strengthening and accumulated stress for optimum microstructure in modern bainitic microalloyed steels	935.659
TGS7	STRAINHARD	Strain hardening behaviour of modern lightweight steels	1 186.604
	DP GRADES	DP grades with improved formability	1 331.269
	LOCALHEAT	Local heat treatment of Ultra High Strength Steels	2 081.548
TGS8	FIRE SAFETY	Cluster of 6 projects on fire safety of steel structures	4 927.823
	HYBLAS	Economical and safe laser Hybrid welding of structural steel	1 711.491
	LWO+ plus PRECO-BEAM	New products based on hot-rolled H-sections for short span bridge constructions (cluster)	1 686.680
	HiVoss	Human-induced vibration of steel structures	369.384
	SECHALO	Facilitating Market Development for Sections in Industrial Halls & Low-rise Buildings	797.061
	PROSSUS	Promotion of steel in sustainable and adaptable buildings	333.462
	VALCOSS	Structural design of cold-worked austenitic stainless steel	271.843
	COMBRI plus COMBRI+	Competitive steel and composite bridges by innovative steel-plated structures	1 894.633
TGS9	DECFLAQ	Decision support system for the comprehensive assessment of flat products quality	1 318.371
	IRSIS	Improved utilisation of results from automatic surface inspection systems	1 796.870
	RAPCOAT	Rapid, reproducible and accurate analysis techniques for coating systems	1 455.443
	THINFILM	Characterisation of thin films on rough steel substrate	1 203.482
	ERAMAC	Emissions reduction through analysis, modelling and control	2 756.856
Total budget of the selected projects in the Steel sector			**60 706.101**

Table 3b. List of Steel projects selected for deep assessment

5.2 Significant Achievements Provided by the Selected Projects

The in-depth assessment of the selected 46 projects (Figure 9) shows the same tendency regarding the achievement of objectives, according to the 4 components (technical, scientific, economic, social), as the global screening of the 198 projects (Figure 2), but the total of answers is closer to 100 %.

For more than 95 % of the selected projects, the technical and scientific objectives were fulfilled with a success rate higher than 80 %. About 2/3 of the selected projects were successful from the economic point of view.

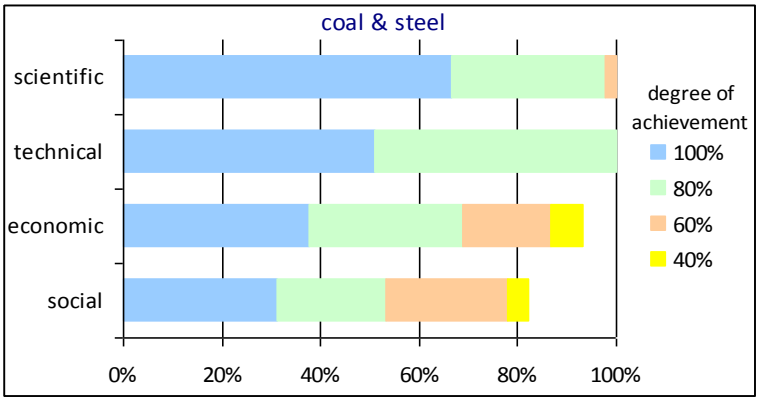

Figure 9. Degree of achievement of the individual objectives

Comment:
The high degree of achievements of the RFCS projects represents a very significant result, considering the level of risk inherent to R&D activities. Even if the social issues are generally not the prime objective of the projects, it is worth to notice that social achievements are registered for more than 50 % of the selected projects.

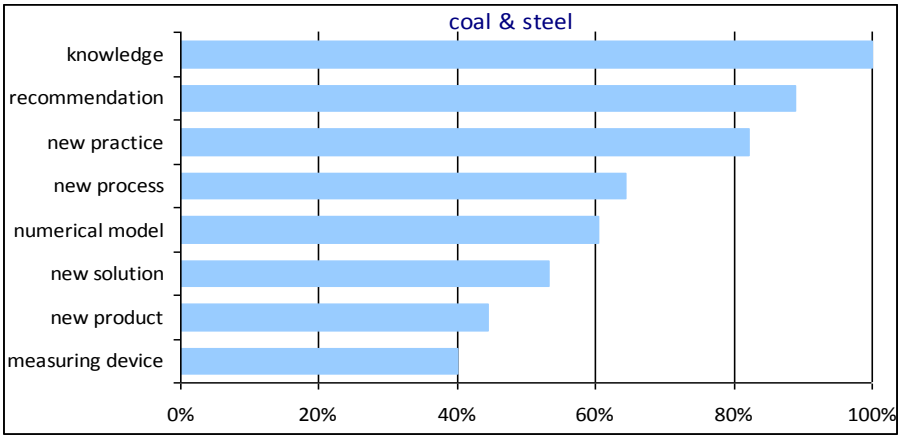

Figure 10. Typology of the outcomes of the selected projects

The nature of the outcomes of the RFCS projects is detailed in Figure 10. All selected projects generate achievements in terms of knowledge. To a smaller extent, they generate recommendations, new processes and practices, numerical models, new solutions and products, and measuring devices.

Comment:
More than 60 % of the projects are providing numerical models, which represents a quite high rate. It reflects the increasing degree of sophistication of the Coal and Steel industry, with the need for models for understanding and control purposes. A similar comment also applies for the measurement devices, which are provided by around 40 % of the projects.

An impressive number of achievements provided by the projects are identified, which contribute to all RFCS objectives in the different technical areas. Tables 4a and 4b list the most significant achievements of the assessed projects, resulting from the present analysis. All of them are intended to be implemented and used in industrial practice as quickly as possible at the level of the beneficiaries and the Sectors.

Comment:
The selected RFCS projects show a wide span of achievements. It is important to point out that these achievements are not only research results. Indeed they can be considered as practically or industrially validated solutions by the beneficiaries, who implemented the developments during the course of the project. These new achievements contribute to increase in a continuous way the knowledge base which is shared between all the members of the sector. Moreover this new knowledge is made available to the whole Coal and Steel community.

RFCS Objective 1 : Improving the competitive position of Community coal	
Coal mining	- Increased productivity by automated longwall equipment - Efficient maintenance procedures - Economic innovative support systems for gate roads - Applying open wireless technologies in underground operations
Coal conversion	- Advanced monitoring devices for coking plants - Testing facilities for improved coal blends - Prolonging the life of coke ovens
Coal combustion	- Efficiency improvement in coal combustion - Improvement of cleaning equipments and heating surfaces - Novel burners with higher fuel flexibility - Advanced on-line methods for ash deposition - On-line process performance calculation methodologies - Circulating Fluidized Bed combustion technology - Co-combustion of coal with biomass - Once Through Supercritical Circulating Fluidized Bed technology - Production of syngas from gasification of low grade coal and biomass - Rotary kiln gasifier with innovative catalytic gasification - Purification of synthesis gas - Oxy-fuel combustion for CO_2 capture - Mathematical modelling and boiler design
RFCS Objective 2 : Health and safety in mines	
Health and safety in mines	- Reduced physical load for miners at the longwall face - Eased maintenance and repair works - Safer working conditions in gate roads - Enhanced performance of mine communication systems
RFCS Objective 3 : Efficient protection of the environment and improvement of the use of coal as clean energy source	
Reduction in emissions and utilization of fly ash	- Examination of slagging and fouling problems occurring in the boilers - Reduction of NO_x emissions - Examination of dioxin releases from coal combustion - Emissions reduction from co-combustion of coal with biomass or wastes - Utilization of fly ash, from power plants, for different applications
Environmentally-friendly products	- Anthracene oil based pitches with lower toxicity - Production of advanced carbon fibres

Table 4a. List of the most significant outcomes from the assessed projects, according to the RFCS objectives (Coal)

RFCS Objective 1 : New and improved steelmaking and finishing techniques	
New/Improved process developments	- Blast furnace process for reducing the reserve zone temperature and cut CO_2 - Low cost process for producing high Mn steels from the scrap-EAF route - Improved burner operation - Process for controlling the liquid flow in the CC mould to avoid defects - New practices to avoid nozzle clogging in continuous casting - New practices to control the atmosphere in the reheating furnace - New developments in asymmetric rolling of slabs - New work roll cooling system in hot rolling - Optimised pickling process
New sensors (incl. exploitation methods)	- Follow-up of the level of liquids in the blast furnace hearth - On-line temperature measurement system in BOF converter - Sensor to predict clogging risk in continuous casting - New system for on-line detection of roll marks on the strip # - On-line residual stress measurement system in large rolling equipments - New on-line gauge for under-pickling detection # - New H_2 sensor for on-line over-pickling detection # - Characterisation of fugitive and stationary emissions (VOC, NO_x, SO_x)
Models	- 3D blast furnace hearth wear thermomechanical model - Fluid flow model of the continuous casting mould - Real-time reheating furnace diagnosis model
RFCS Objective 2 : RTD and the utilisation of steel	
New products and dedicated process	- Improved process design for X100, X120 grades - New strain hardening process for Advanced High Strength Steels (AHSS) - Improved twining process for high strength-high ductility steels - New annealing process for hot dip galvanisation of TRIP and DP steels - Local heat treatment of AHSS by laser or induction - Optimisation of the properties of TRIP, DP, Q+T steels - Development of lightweight steels for automotive and construction markets - New bainitisation process (vacuum technologies) - Special enduring beams for bridge construction - Beams with large web openings for light long-span floors - Hybrid welding process for beams
New sensors, measurement systems, testing procedures, new design methods	- System for fast and quantitative on-line analysis of organic/inorganic coatings - New sensor for on-line measurement of surface waves on moving strip # - Fast and accurate surface inspection system for coils (new ASIS) - New testing procedure for fire resistance of steel structures - New design methods for structural safety of constructions: seismic , explosion resistance - Updating of the European standards Eurocodes for construction
Models	- Material science model for prediction of microstructure, applied to AHSS - Numerical metallurgy; micro-macro scale models for steel microstructure and properties - Strain hardening models of AHSS - Decision support models for controlling the automatic surface inspection systems
RFCS Objective 3 : Conservation of resources and improvement of working conditions	
Process, Procedures and Methodologies	- Process for using alternative raw materials and fuels, including carbon neutral materials - Remote supervision of the risky zones around the blast furnace (tuyere and hearth areas) - Reduction of emissions of VOC, SO_x, NO_x, fumes, from the coke oven doors - Reduction of NO_x and PAH during steel ladle heating - Decrease of the number of break-outs at continuous casting - Reduction of NO_x emission in burners and reheating furnace - Reduction of risk of fire in pickling lines - Suppression of welding fumes due to hybrid welding - Reduction of accidents during construction using pre-fabricated products

Table 4b. List of the most significant outcomes from the assessed projects, according to the RFCS objectives (Steel) [*#: system leading to a commercial development with an equipment builder]*

5.3 Assessment of the benefits for the Beneficiaries and the Sectors

During the process of assessment, the project coordinators and the interviewed people have been requested to indicate in which area each selected project had generated significant benefits, among a list of 20 possible categories. Figures 11 to 14 represent, for both sectors, the percentage of projects delivering benefit in each category. Each benefit is scored from "excellent" to "very poor" whereby the ratings "poor" or "very poor" were almost never attributed, and are therefore not reported in the figures. The complement to 100 % corresponds to the projects for which the benefit is not relevant.

For the Coal and Steel projects, all the coordinators and interviewed people expressed a unanimous opinion that the increase of knowledge was by far the most important benefit from the projects. The wording "knowledge" in fact covers a large variety of meanings: the RFCS projects are considered to produce basic knowledge as well as very practical operational know how, ready for industrial implementation. This valuable advantage of the RFCS projects results from the high quality of partnerships, involving in one project team highly specialised academic laboratories, research organisations and industrial plants. Complementary skills in a given domain are thus dedicated to solving the problem raised by the project. Moreover, as the acquired knowledge is very often encapsulated in generic models, the dissemination of the new knowledge is made quite easy.

5.3.1 Coal Projects

As indicated in Figure 11 the increase of knowledge creates the most important value and that is valid for all assessed projects. A very good example is the geotechnical modelling which has been executed in several projects and by different experts. Due to the combined efforts the expertise has been substantially enriched and is very valuable to predict the behaviour of the carbon strata.

Training and education is rated second best. Indeed there is a strong link between knowledge, training and education and it indicates that the improved expertise is passed to concerned employees within the company. The extension of knowledge-related capabilities seems to be the most substantial outcome of the projects at the beneficiary level.

The next important outcome is related to new or improved process and - it covers a similar topic - new solutions. With regard to the general objective of a research project this underlines the scientific approach of the RFCS projects. The automated shearer loader, monitoring tools for coke ovens and new combustion technologies can be considered as exemplary.

The Council decision explicitly noted to strengthen the competiveness of the related industry. The analysis proves that economic benefit and cost reduction have become major outcomes of the assessed projects. More specifically on the cost reduction issue, this is of paramount importance for the coal-fired power plants as it is essential to introduce new technologies, such as circulating fluidized bed technology and gasification technologies, as well as new equipment.

In addition to that, improved product quality and new or improved products are important to stay in the market and contribute to a forward-looking business. A promising outcome for example is the generation of advanced carbon fibres from anthracene oil based pitches derived from coking plants.

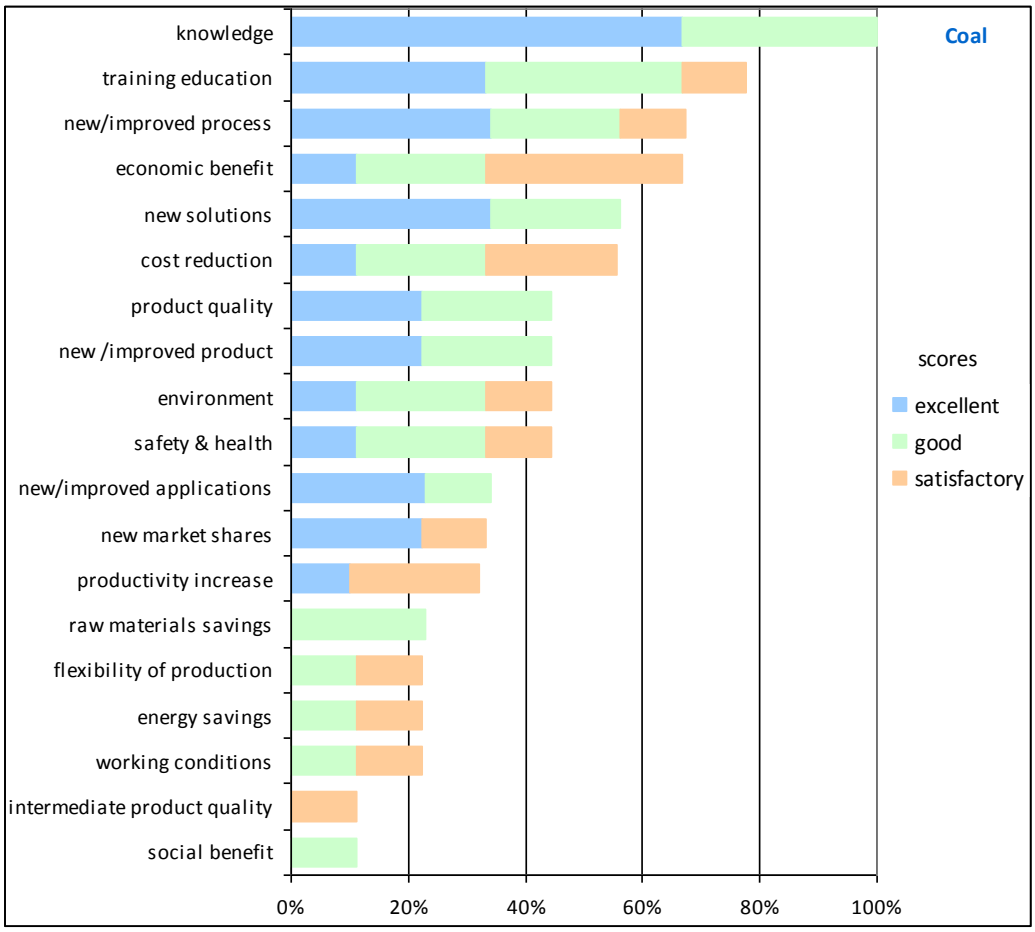

Figure 11. Contribution of the projects to the benefit for the beneficiaries (Coal projects) *(the complement to 100% corresponds to the projects for which the category of benefit is not relevant)*

The top ten of outcomes also covers environmental improvement and occupational health and safety.

Environment is a very important issue in the electricity generation, taking into account the new environmental legislations and the measures required to gain emissions reduction. Improving the safety in coal mines is undoubtedly a most challenging necessity. As this analysis examines the beneficiary level it is a most welcome indication that real and notable improvements of safety and environment have been achieved.

In a next step the analysis of the selected projects has dealt with the benefits at the sector level. As a general rule, the ratings of the different benefits for the sector are very similar to those for the beneficiaries. It was expected and no surprise, that knowledge, training and education are named as the most important outcomes of the selected projects. Next to that the economic benefits proved to be valuable which have an essential impact on the competiveness of the Coal sector.

In a slight deviation to the beneficiarie's level, safety and health

are regarded as an even more important benefit for the Sector. It is assumed that the projects strengthen the general awareness and commitment to safety related issues. And, as experienced in safety related projects, the collaboration between European partners is particularly fruitful with regards to safety issues.

Conclusion:
In the Coal sector, the increase of knowledge and the dissemination of expertise in the company through training and education are creating the most important value to the projects beneficiaries. The development of new processes and new solutions along with the economic benefit and cost reduction issues are rated very high. This ranking reflects that the RFCS projects contribute to maintaining or increasing the competitiveness of the related industry by providing innovative solutions, with due consideration to economic issues.

Environmental improvement and health and safety are also considered among the most important benefits generated by the projects.

The ranking of benefits shows the same trends as at the beneficiaries' level, with Safety and Health achievements being scored even at a higher level. For safety related issues, the networking of partners, fostered by the RFCS programme, represents a valuable source of progress.

5.3.2 Steel Projects

In the Steel Sector too, knowledge is considered as the major benefit generated by 100 % of the selected projects. Training and education, which is strongly connected to knowledge, is also rated at a very high level.

A more detailed analysis shows that it is worthwhile to assess the steel projects in 2 different categories showing a different benefit mapping. On one side the projects dealing with process improvement and development (basically projects from TGS1, TGS2, TGS3, TGS4, TGS5), on the other side the projects dealing with the development of new products (TGS6, TGS7, TGS8, TGS9 ; TGS6, devoted to basic science in steel metallurgy, exclusively supports the product development, and is therefore classified in the second category.

Regarding the steel projects, the benefits generated for the beneficiaries and for the sector are very similar; therefore they are analysed in a common way in the following figures.

- **Steel process development domain**

As can be seen from Figure 12, more than 90 % of process oriented projects are considered to deliver significant benefits, expressed in terms of process improvement or new processes: this item also includes new sensors and advanced instrumentation of process, and advanced control tools. The most significant process developments have been listed in Table 4b.

Economic benefit and cost reduction are following in the row: it is clear that in the upstream area the cost issues are dominant, and the projects are considered to contribute at a high degree to the reduction of cost, and thus to the competitiveness of the business. This is in line with the expectations.

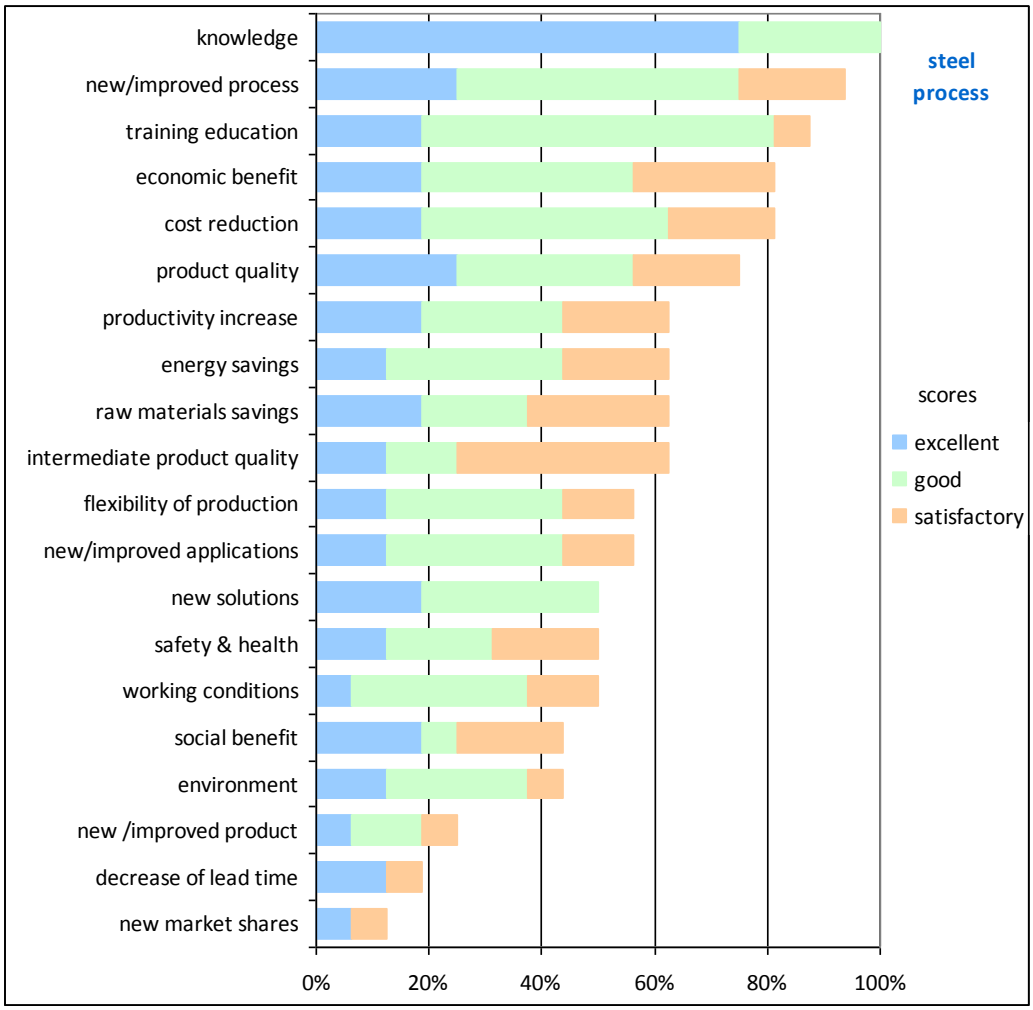

Figure 12. Contribution of the projects to the benefit for the beneficiaries (Steel Process Development projects) *(the complement to 100% corresponds to the projects for which the category of benefit is not relevant)*

Two significant examples are illustrative. The projects dealing with the hearth of the blast furnace have provided new control tools for a better knowledge of the internal state of the furnace, allowing smoother operation and an extension of the campaign life of the blast furnace. This has a strong impact on the global economics of the ironmaking area, with a significant cost reduction of hot metal, due to better use of the assets. In the rolling area, an innovative system for cooling the work roll has been developed, leading to a significant increase of the service life of the rolls, and a decrease of the cooling water consumption, both effects contributing to cost reduction.

Mastering the product quality along the production chain up to the final product always remains an important issue, receiving thus a great deal of efforts. More than two third of the selected projects have provided benefits on quality issues. New sensors, often derived from the high tech industries, have been developed to assess on-line

the quality of the intermediate products, to detect as early as possible any deviation. This will initiate the corrective actions to avoid downgrading or re-routing of products, which are very costly operations in continuous production lines. Typical examples are the early detection of roll marks on the moving strips, surface inspection of sheets, and detection of non-appropriate bulk and surface geometry of products (flatness, waviness…). This, in turn, leads to a significant decrease of the cost of the inspection lines.

The benefit in terms of productivity increase appears in a second row. Generally, the productivity represents a potential benefit. Indeed the real possibility to take profit from productivity increase merely is mitigated by the market situation. Regarding productivity increase, many projects have allowed to reduce the frequency and extent of incidents, thanks to new sensors and more accurate control tools for early detection and prevention of the incidents. Typical examples are tuyere losses in the blast furnace, break-outs at the continuous caster, rolling cylinders breakage in the rolling mill. A tighter control of the operations also contributes to increase the success rate of operations, avoiding time consuming corrective actions, like re-blow at the BOF converter, over-pickling or under-pickling on the strip pickling lines.

Energy and raw material savings are still included in the top ten benefits. Even if energy and raw materials issues are not always the prime objective of some projects, they are indirect benefits of a large proportion of projects. As an example, projects have been devoted to develop innovative and intelligent systems for a better control of the burners and improvement of the energy efficiency and energy flexibility of reheating furnaces.

More than 40 % of projects have, at least, a satisfactory impact on health and safety, working conditions and social issues. In this case too, it is an indirect benefit from the projects allowing to implement remote control of the most difficult working places (tuyere and hearth area around the blast furnace, casting floor at blast furnace or continuous casting, zone close to the zinc pot at hot dip galvanisation) or to avoid incidents, like break-outs at the blast furnace or casting area, or fire at the pickling line.

The environmental benefit is quoted for about 40 % of the selected projects. One project has been fully dedicated to CO_2 reduction issues, in connection with the ULCOS program. It has provided short term solutions to significantly reduce the CO_2 emissions at the blast furnace, without any extra cost or negative impact on productivity. The difficult question of fugitive emissions of pollutants (VOC, SVOC, SO_2, NO_x, dust, particulate emissions) in the cokemaking area has been addressed by another project, providing new and accurate measuring methods to characterise the emissions.

- **Steel Product development domain**

As can be seen from Figure 13, knowledge and training and education are evaluated as the strongest benefits from the selected projects. In the field of product development it is recognised that the best knowledge in steel metallurgy is required. The RFCS programme also supports very basic studies in metallurgy, aiming at a detailed knowledge of the relationships between steel microstructure and mechanical properties.

A series of projects have contributed to develop advanced numerical models, able to predict, with an outstanding accuracy, the mechanical properties of steel from the processing conditions. This concept of "numerical metallurgy" is of a great help to design new steel

grades meeting the customer's requirements. The amount of testing work is reduced and the time to market of the new product is shortened, which represents a strong competitive advantage.

Next to knowledge and training-education, the second major benefits concern the development of new solutions, new products, and the improvement of quality, all topics leading to the increase of market shares: new products put on the market or higher penetration of existing high quality products. It is interesting to notice that the projects in this area are also addressing cost issues, reflected by the high rating of the economic benefit. These projects largely contribute to enhance the position of steel in the competition with other materials: aluminium or composites in the case of the automotive market, concrete or wood in the case of the construction market.

The development of Advanced High Strength Steels (AHSS) for the automotive market is a vital issue for the steel industry. This evolution is triggered by the necessity to meet the targets of fuel consumption and CO_2 emissions of the cars. The weight reduction of the cars is clearly one part of the solution, in which steel can play a decisive role, considering the outstanding properties of the new AHSS grades. It is important to notice that some projects were dedicated to the optimisation of the production processes of these steels, in the field of steelmaking, hot and cold rolling, and zinc coating. As a consequence, there are large opportunities to increase the market shares of AHSS, provided the manufacturing routes of those products are operational and cost effective.

Regarding steel for the construction market, a great deal of projects have been carried out to improve the penetration of steel, involving the development of new products and large actions of promotion of steel towards the designers and architects: examples are prefabricated composite beams for bridge construction, long span girders for multi-storey buildings, hot rolled sections for industrial halls or low-rise building, anti vibration floors, cold worked stainless steels for aesthetic parts in building, high strength steel composites with concrete for bridge structures. The development of the innovative Natural Fire Safety Concept, considering not only the fire resistance of individual components but the fire safety of the building as a whole, has resulted in the successful introduction in the Eurocodes. This has opened the way for an increased use of structural steel components in buildings, where it was previously too expensive or even forbidden.

The benefits in terms of new process developments are rated at a significant level, even for projects devoted to product development. This highlights the strong advantage to address simultaneously the product development and the process issues underlying this development. Considering the process-product co-development as a whole guarantees a quick response time and represents a benefit for the time-to-market of new products. Several projects were precisely aiming at developing the new processing routes for producing steels with high resistance and high formability (Dual Phase, TRIP, TWIP steels), which are key components for the lightweight complex parts for cars. In the race towards weight reduction, the AHSS are in hard competition with aluminium, and the possibility to design and produce very complex parts at moderate cost gives a significant advantage to steel.

In the domain of product development, the selected projects were considered to have only a moderate impact on environmental, safety, health and working conditions. The corresponding benefits are considered as of second order.

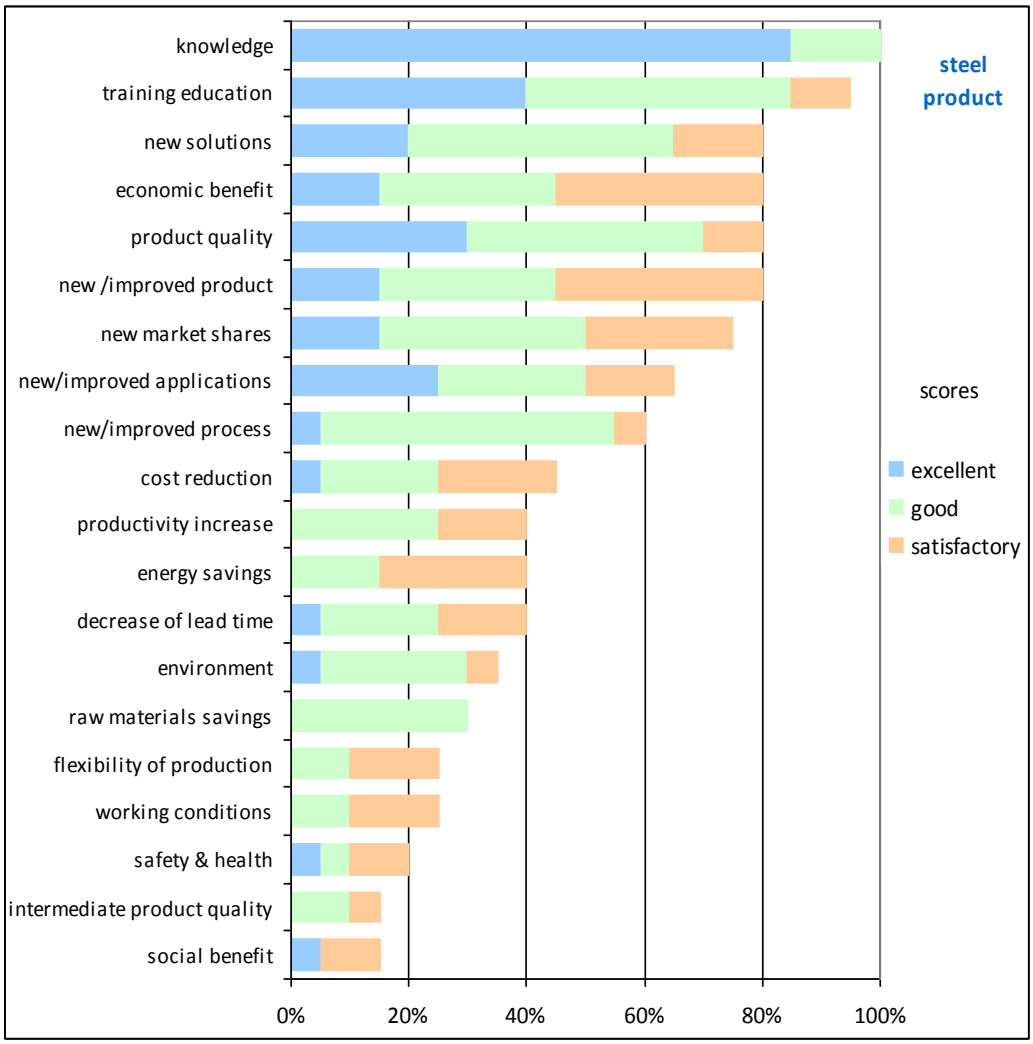

Figure 13. Contribution of the projects to the benefit for the beneficiaries (Steel Product Development projects) *(the complement to 100 % corresponds to the projects for which the category of benefit is not relevant)*

Conclusion:
In the Steel sector, the increase of knowledge and its dissemination through training and education are considered as the most important benefits generated by the projects at the beneficiaries and sector levels. The development of new or improved processes, new products and new solutions are scored as very important. Indeed innovation in process and the development of new products for the customers are key achievements to ensure the sustainability of the Steel sector in the future. The important score attributed to cost related issues highlights the fact that in heavy industries the stress on cost is prevailing, even for innovative products. In the upstream part of the manufacturing routes raw materials and energy savings are highly valued. Health, safety and improved working conditions are addressed in many projects.

5.4 Benefit for Society (Coal and Steel Sectors)

The selected Coal and Steel projects deliver similar benefits to Society. The increase in knowledge is considered as the major benefit, with a contribution of about 100 % of the projects.

More than 80 % of the selected projects are considered as contributing to the European competitiveness: this reflects the development and sharing of new knowledge, leading to the effective implementation of new technologies in the Coal and Steel sectors. Innovative products, generating new market shares for Europe, and new applications are keys for the preservation of the European competitiveness in the global world. Moreover, some of the RFCS projects also extend their benefits to the industrial customers of the sectors, and thus finally to the European product consumers. This is in particular the case for the steel products dedicated to the automotive and construction markets.

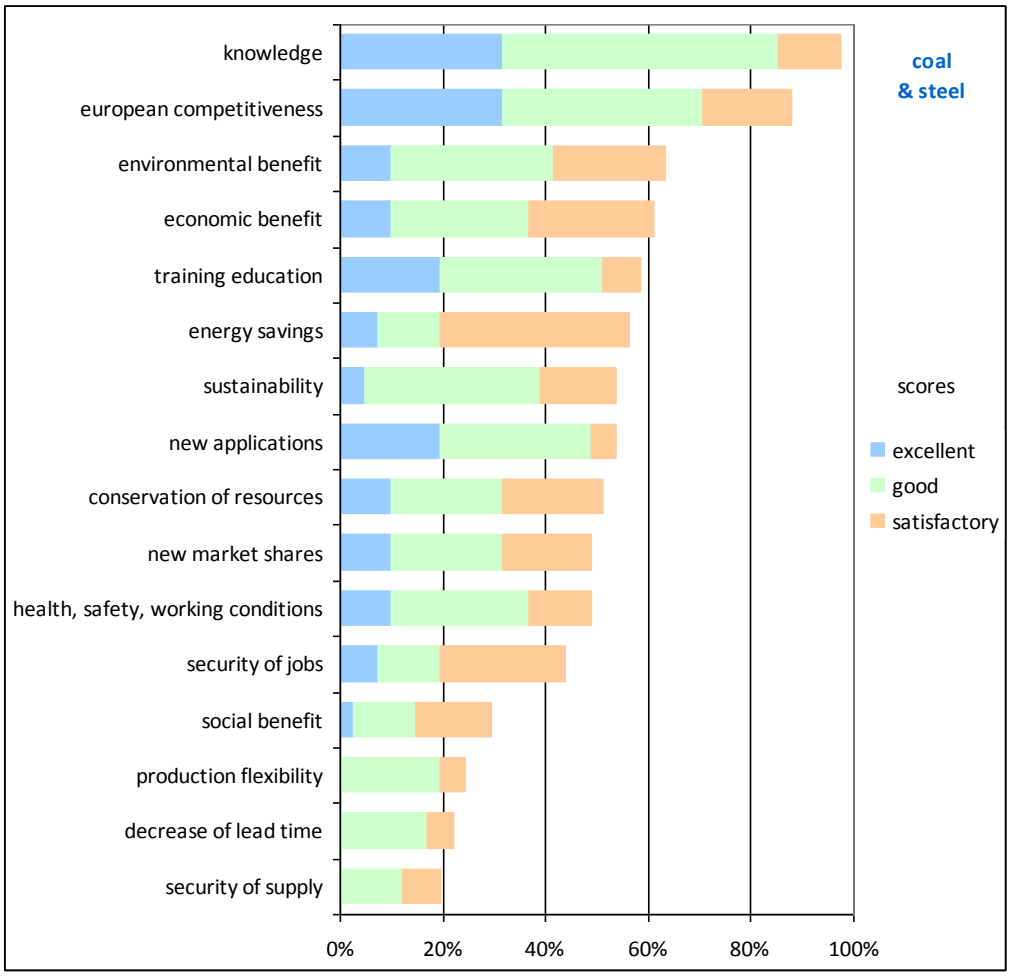

Figure 14. Contribution of the projects to the benefit for the Society (Coal & Steel projects) *(the complement to 100% corresponds to the projects for which the category of benefit is not relevant)*

The environmental issues and the global sustainability of the Coal and Steel sectors are addressed by about 60 % of the selected projects: the reduction of green house gas and other harmful emissions, the development of environmentally lean processes, the promotion of clean technologies of use of coal have a positive impact on the environmental situation of the European citizens.

The conservation of resources also represents a very valuable benefit of the projects; this is of strategic importance in the present times characterised by the scarcity and the high cost of resources in Europe. In the Coal sector several projects address the issues concerning the optimum mining and use of the European coal resources. In the Steel sector, the race towards lightweight products, especially for automotive, significantly contributes to the reduction of fuel consumption and CO_2 emissions of the cars, and thus a decrease of the oil imports: it is agreed that decreasing the weight of a car by 100 kg allows a reduction of fuel consumption by 0.4 to 0.6 l for 100 km.

About 50 % of the selected projects are considered to have a beneficial effect for improving the safety, health and working conditions. Some projects are clearly focused on those issues, like the projects dealing with safety in the coal mining. But, as a welcome secondary effect, some projects bring about significant improvements in the field of health, safety and working conditions. The development of new sensors, supplemented by models, assists the operators and enables to build remote working places, avoiding the physical presence of the workers in dirty, hot and dangerous areas. The decrease of harmful gaseous or particulate emissions has a positive impact on the health situation in and around the industrial plants. The development of the use of AHSS in the car industry leads to an improvement of the active and passive safety behaviour of the car, with significant benefit for the car passengers and for the pedestrians, in case of accidents.

The security of jobs is reported as a significant benefit for about 50 % of the projects; most probably a parallel can be drawn with the impact of the projects on the European competitiveness.

Conclusion:
The RFCS projects positively contribute to the major challenges the European Society is facing to remain sustainable and competitive. The increase of knowledge is considered as the prime benefit. The development of new technologies, new steel products and new applications are recognised to heavily contribute to the European competitiveness in the global market. The development of new technologies in the electricity generation provides better living standards for the citizens in Europe. The conservation of resources represents a significant outcome of the RFCS projects, contributing to the global sustainability of Europe, facing high cost and critical scarcity of raw materials and energy. In addition, the projects are considered to help in improving the health and safety conditions of the people at their working place and the citizen using steel products and goods. Finally, these achievements exert a welcome effect on the security of jobs.

5.5 Dissemination and industrial exploitation of the projects

- **Dissemination**

The efficient dissemination of the project results represents a key factor for the whole profitability of the RFCS research programme. Indeed the findings obtained in the projects are intended to be shared and spread out beyond the beneficiaries of the project team, in the Coal and Steel sector, in the technical and scientific community, and in the European Union in general. It is a matter of full financial return from the money spent in R&D, and also of boosting the knowledge development within Society, including Academia, the large industrial companies and the Small and Medium Enterprises (SME).

A first step of dissemination of the project results is within the project team and with the members of the Technical Group in charge of monitoring the project, during the course of the project; the progress of the work is reported during meetings and in periodical reports. This is a very useful means to develop networking between experts and researchers in the given domain. On completion of the work, the final report is made open to the public, after approval by the Technical Group and the European Commission. This report comprises an assessment of the exploitation of the results and their impact for the beneficiaries, and some recommendations for the dissemination of the results in the Coal and Steel sectors.

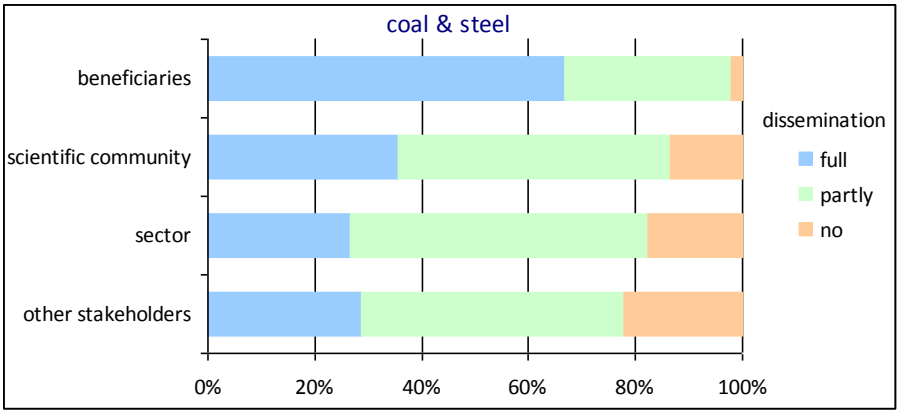

Figure 15. Degree of dissemination of the project results (Coal & Steel)

The degree of dissemination of the project results is high at the level of the beneficiaries (Figure 15): two thirds of projects are fully disseminated and 95 % are, at least, partly disseminated at this level. It decreases for the other stakeholders, the sector and the scientific community, but in all cases, the proportion of projects not spread out remains low, between 10 and 20 % only.

The degree of dissemination of the results, at least partly, in the scientific community is high, around 90 %. This implies that the scientific community is reasonably well involved in the Coal and Steel research and that RFCS projects results contribute to increase the level of scientific knowledge. Many RFCS projects have supported PhD theses, indicating the high level and originality of the developed knowledge.

Dissemination at the sector level is mainly partial. The reasons are well balanced between different causes (Figure 16). Technical difficulties are the major reason (about 30 %) for a partly dissemination. The costs of implementing the transferred results, along with the impact of local technical conditions, account each for about 20 %. The lack of information or the existence of alternative solutions are second order reasons. Satisfactorily, the lack of transferable results does not represent a strong reason for poor dissemination.

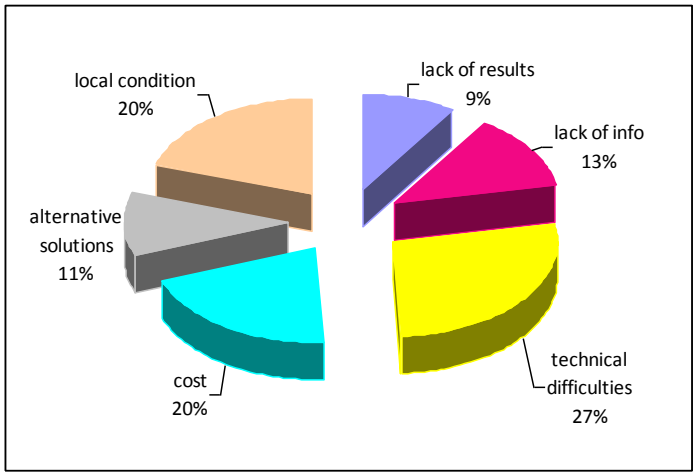

Figure 16. Reasons for only partly dissemination or application of project results in the sectors (Coal & Steel)

Comment:
This analysis suggests to address the transferability issues in a more pronounced way during the course of the project, for example by promoting solutions as generic as possible. This is especially relevant for the transfer of models or sensors

Among different means used for dissemination (Figure 17), the Final Report is, by far, the most common and efficient, even if some improvements can be proposed (see Monitoring Report [1]). Publications in technical journals and presentations at conferences are also frequently used means to spread out the results of the projects. It has become standard practice to present RFCS results in the most relevant international conferences. Less than 50 % of projects have resulted in workshops and in web sites, despite the fact that these are considered as the most efficient means for dissemination.

Workshops and web sites have been largely used in the domain of TGS8 (Steel products and applications for building, construction and industry) and to a lesser extent in the Coal sector. In TGS8, it has almost become a standard practice to promote the use of the project results while organising workshops for the potential users and developing web sites with possibility of free downloading state-of-the-art reports, including software. In the other domains, the use of workshops or web sites is very scarce, and should be developed, as recommended in the Monitoring Report [1].

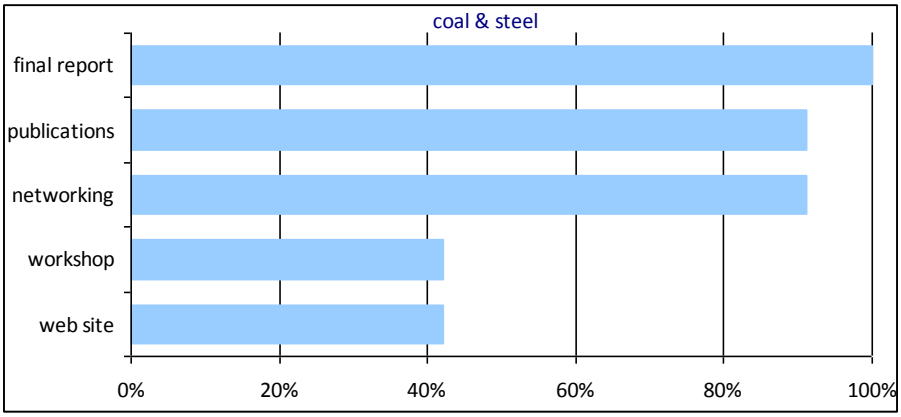

Figure 17. Means used for the dissemination of the project results (Coal & Steel)

- **Exploitation at the beneficiaries level**

At the beneficiaries' level, about 50 % of the projects have resulted in commercial exploitation, which is a rather good figure for R&D. Moreover, some individual projects have not directly led to industrial practice, but to another Research or Pilot and Demonstration project, which can be a preliminary step to prepare the industrial exploitation. This happens in about 70 % of cases, reflecting the fact that in the heavy Coal and Steel industries innovation requires time. It is often necessary to work with clusters of projects, organised in an appropriate and timely way, to reach industrial implementation.

The development of road maps, addressing the industrial priorities, appears thus as useful approach to prepare in advance the series of projects leading to effective industrial application [3].

As regards exploitation of the projects results (Figure 18), a large proportion of projects have resulted in technology transfer, which represents a first step for further industrial dissemination. The transfer took place between the project partners, with the sector and also with engineering companies. This especially occurred when the projects led to new measuring devices or sensors. In several projects, innovative sensors have been conceived by the researchers and their engineering and commercialisation have been placed in the hands of specialised European companies, able to market the product in Europe or worldwide.

A number of patents have been filed in relation with the projects; on average one project out of five has led to at least one patent, which corresponds to a total of 11 patents related to the 46 selected projects. Most of them are dealing with new measuring techniques. Considering this figure, it must be recalled that it is also strongly dependent on the individual patent policy of the members of the project consortium. Furthermore the action of patent filing often occurs after the end of the RFCS project.

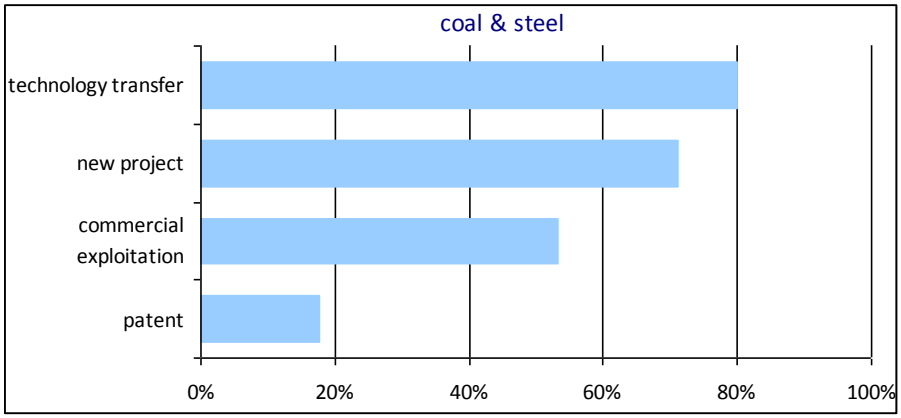

Figure 18. Type of exploitation of the projects results at the beneficiaries level (Coal & Steel)

Conclusion:
The degree of dissemination of the projects results is very high at the level of the beneficiaries and slightly less, but nevertheless very significant, at the sector level. This emphasises the quality of the technical exchanges between the partners inside the project consortium and the efficient transfer of knowledge inside the sectors. Networking between specialists, fostered by the active discussions during the regular TG meetings, certainly contributes to spread out the projects results within the sectors. The efficiency and swiftness of the transfer could be improved by an increased use of workshops or web sites dedicated to updating the state-of-the-art on focused subjects.

Individual projects led to commercial exploitation at the beneficiaries' level, and more often to a new project. It is useful to combine several projects in a cluster way to solve complex industrial problems. The use of pilot and demonstration projects appears as an appropriate way to complement R&D projects up to the final industrial exploitation.

5.6 Summary of Benefits

Conclusion:
There is a unanimous consent that the most important benefit from the RFCS projects lies in the development of new knowledge, which can be directly used for the training and education, inside the plants and sectors, as well as in the society. For 100 % of the selected projects the gained knowledge is quoted as excellent or good.

In both sectors, Coal and Steel, the financial returns, expressed through the criteria cost reduction or economic impact, are rated as the following important benefit. It is considered that the efforts and money – Community money and Industry money – invested in the RFCS Research projects produce operational results that effectively contribute to the economic sustainability of the sectors.

In both sectors again, the development of new processes, new solutions, and new products is rated at a quite similar level as compared to the economic benefits. This result indicated the recognition of the significant impact of the RFCS projects on the development of Innovation and its deployment in industrial practice. It is therefore important to keep promoting the Innovation character of the RFCS projects.

In the Coal sector, progress on the environmental issues and on safety and health are considered as significant benefits. Indeed several projects are especially dedicated to those subjects, namely safety in underground mining or the development of techniques for the use of coal for clean energy production.

In the Steel sector, the projects devoted to process improvement provide significant benefits in terms of quality mastering as well as working conditions. The latter aspect is important as it is worthwhile to improve the working conditions in a harsh and critical environment, by developing automation, and remote sensing and control tools. Environment is also a key issue in the steel production processes. The RFCS projects have provided numerous solutions for decreasing the environmental footprint of the processes, by direct action on the process itself or by proposing end-of-pipe solutions.

The projects in the downstream area of steel production are in direct connection with the customers. It is recognised that the projects have significantly contributed to develop new products, directly aligned with the customer's needs, and consequently to generate new market shares. Numerous examples are to be found in the automotive market and in the construction markets. The projects directly contribute to maintain, or strengthen the position of steel, in strong competition with other materials, like aluminium, composites, concrete or even wood. The RFCS projects, involving very positive partnerships between competitors in steel production, are unique tools for promoting the outstanding properties of steel, in a common front facing up other materials.

Regarding the benefits for Society, beside the increase of knowledge, the RFCS projects are considered as strongly enhancing the competitiveness of Europe in the present challenging world market. Next comes the environmental benefit: the RFCS programme is acknowledged to contribute to the global mastering of the environmental footprint of the Coal and Steel industry, for the benefit of the European citizens. It also significantly contributes to maintain the competitiveness and sustainability of the European industry, more than just Coal and Steel.

6. Detailed Benefit Analysis of the Selected Projects

A detailed analysis of the quantitative benefits generated by the projects at the beneficiaries' level has been carried out by the Rapporteurs and the project coordinators. The benefit figures rely on industrial data provided by the partners involved in the project and gathered by the coordinators. A series of significant and representative examples is presented in this chapter. The analysis reveals that the quantitative benefits generally fall into one of the six categories:

- the financial return
- the environmental benefits
- the health and safety issues
- the development of new knowledge, including modelling
- the development of new applications, including sensors and measuring techniques
- the means for better use of coal and steel

6.1 Financial return of the projects

Most generally, the quantitative benefits at the level of the plants of the beneficiaries can be expressed in terms of financial returns. In most cases, the benefits are industrially proven, whereas sometimes they remain potential.

R&D is a long term investment, and many companies have now a system in place to evaluate the value creation of research projects. Several methodologies have been proposed by specialised offices to carry out such analysis. The present assessment exercise does not intend to present an exhaustive analysis of value creation. Only a few typical examples, representative of the RFCS projects, will be illustrated below.

First of all, it must be made clear that the benefit generated by the R&D projects cannot be solely attributed to research. The technical progress in the industrial plants is managed by the plant people, involved in continuous improvement of their operations. Research can be considered as a promoter or catalyser which provides solutions for triggering the progress and introducing Innovation. In other words, the technical progress is a fully collaborative process, and it is useless to try to determine the respective parts of each partner in the generated benefit.

The financial returns are classified in different categories: reduction of operating costs, productivity increase, energy and raw materials savings, and development of new market shares.

6.1.1 Cost reduction

- More efficient cleaning concepts for stepping up availability of lignite-fired power plants (LIGPOWER)

The objective of this demonstration project was to test improved cleaning equipments, and new easy-to-clean heating surfaces in boilers of coal-fired power plants, especially lignite-fired. Optimising the cleaning process is important, as fouling and slagging problems lead to a progressive degradation of the energy efficiency of the boiler. Furthermore using non appropriate cleaning systems may damage the heat exchanger tubes. The proper use of the cleaning facilities prevents power plant outages and reduces the overall emissions, by

avoiding unscheduled and extra start-ups.

Four selected cleaning facilities have been tested on commercial boilers of 600 and 300 MW. The project has resulted in a leap in the knowledge and technology of coal-fired plants. The project team has identified the most suitable cleaning methods and those non suitable, providing the Coal sector with very clear results for further applications.

The clear results help in the selection of cleaning systems, avoiding wrong investments, and thus saving money

Benefit of project LIGPOWER:

An increase of the power plant availability of 1 % of the company's 600 MW units leads to an increased earnings of roughly 1 M€/y. In addition the project induced a cost reduction of around 10 M€ in the company, avoiding false investment.

- Enhanced Blast Furnace Operation

The blast furnace constitutes the heart of the integrated steel plant, and the economics of the plant strongly depends on the blast furnace performance; indeed the cost of hot metal represents about 50 % of the price of the hot rolled coil. Considering the huge investment required for the revamping of a blast furnace, its campaign life, which is currently limited by the life span of the hearth, plays a decisive role in the long term economy of the plant. This project belongs to a series of incremental projects contributing to gain a comprehensive understanding of the hearth wear phenomena. Different new sensors have been developed and implemented for monitoring the actual wear state of the hearth and controlling the liquid flow in the hearth, which is one major cause of refractory wear. They were complemented by new thermal supervision models for continuous measurement of the residual thickness of the refractories. This allows to detect in advance the degradation phenomena and to take appropriate preventive actions.

In another plant, it has been observed that the liquid level monitoring tools, allowing a better drainage of the hearth, have contributed to a better control of the thermal state and led to a significant reduction of the coke rate, by about 7 $kg/t_{Hot\ Metal}$. Furthermore, due to a tighter control of the liquid flow in the hearth, the number of tuyere break-outs was reduced, and consequently also the number of unscheduled stoppages. This has a clear beneficial impact on the productivity and the cost, as well as the safety of the workers.

Benefit of the project Enhanced Blast Furnace Operation:

The evaluation of the benefits has been carried out by the project partners. In one plant it has been considered that the implementation of the different tailor-made solutions proposed in the project can increase the campaign life of the blast furnace by one year.

This corresponds to a decrease of the cost for relining and stoppage by about 5 %, or 5 M€ for an average blast furnace.

At the level of this plant (4 $Mt_{Hot\ Metal}/y$), an additional benefit in terms of coke rate reduction has been registered. It corresponds to a coke saving of about 30 000 t/y or approximately 7 M€/y.

6.1.2 Productivity improvement

In a heavy capital intensive industry, operating at highest possible productivity is always favourable to reduce the impact of fixed cost and improving the global economics. However the optimum productivity first depends on the market: in continuous manufacturing processes, involving several steps in series, the overall productivity is generally determined by the slowest step. Consequently, the benefit from increasing the productivity of one step can only be effective if this step is bottleneck. As the situation can change according to local conditions, time and economic climate, the extrapolation of productivity benefits from one plant to another must be analysed with care.

- New mechanisation and automation of longwall equipment (NEMAEQ)

European coal producers are facing the challenge that the productivity in underground operations is less than mines overseas, as a result of the structure and depth of the deposits in Europe. Automation and mechanisation are thus key factors to increase the productivity of longwall and drivage equipment. To take full advantage of a higher automation it is essential to enhance the reliability of the equipment. The project has resulted in the development and implementation of full shearer loader equipment, facilitating the complete winning process without any manual operation. Beside the high technology, another reason for the success of the project is the decisive effort on the reliability of the components, the data communication systems and the software tools in this harsh environment. The project has fully proven that, even in a very difficult and challenging environment, the automation of mining procedures is now possible.

The automated shearer loader is in operation at the German RAG company, where the operational capability has been evaluated. First, the new shearer loader has to be manned with only one operator instead of two. Second, compared to the average of all 8 classical shearers, the productivity could be increased with the new automated shearer from 60 t_{coal}/man/shift to 110 t_{coal} /man/shift and the area rate of advance, a key factor for the efficiency, was improved by about 60 %, from 3.9 m²/min to 6.3 m²/min.

Another substantial benefit is related to the manufacturers of mining equipment in Europe. These manufacturers face the challenge that they have to offer the most modern technology otherwise low cost equipment from different countries will be chosen. Innovative features, detailed engineering and a reliable technique tested in the harsh environment of deep European coal mines - those are very valuable arguments enhancing the market share of European manufactures. The development of the fully automated shearer gave a very remarkable input to strengthen their position. And several European spin off companies have been launched in the frame of the project, which are now integrated in different industrial applications in the field of infrared technology, radar sensors, and seamless WLAN roaming.

Benefit of the project NEMAEQ:

The productivity increase at the face achieved by the automated shearer loader has been proven by the beneficiary as very significant, up to 60 %.

Furthermore, it can be mentioned that the manufacturers of mining equipment in Europe have been strengthen in their position with regards to the global market.

- Application of direct optical temperature measurement in steelmaking process (DOT-Application)

An efficient control of the Steelmaking process relies on the knowledge of liquid steel temperature throughout the process, which can result in increased productivity as well as energy savings. The project investigated the feasibility of using optical fibres to measure the steel temperature in BOS converters. After selection of the appropriate fibre, the optical on-line measurement system was found to be reliable for determination of the blowing end point with respect to the bath temperature. In addition, the accuracy of the results was found to be sufficient for process control.

The validation of the measurement system was carried out at industrial scale on a large number of heats in the BOS converter of the project leader. By use of the temperature measurement system it was possible to decrease the number of heats with a temperature deficit as well as an over-temperature: eventually re-blowing or cooling can thus become unnecessary.

This new technology, developed on BOS converters, can easily be implemented on other melting or refining vessels, like EAF or AOD/VOD converter.

Benefit of the project DOT-Application:

The gained benefit can be expressed by the reduction of the re-blow rate of the converter. In one plant the tap-to-tap time has been reduced by more than one minute, leading to a productivity increase of 1.8 %. The corresponding benefit evaluated by the plant team, has reached 3.7 M€/y/converter. Furthermore, the reduction of re-blows has allowed a saving of oxygen estimated at 2.7 $m^3/t_{Hot\ Metal}$,

- Optimised productivity and quality of pickling by on-line control of pickling surface (HIGHPICK)

The steel pickling process aims at preparing the strip surface for the downstream rolling and coating steps, by dissolving in an acid bath the impurities still present on the surface (remaining scale, surface defects …). The process must be tightly controlled, in order to avoid under-pickling (incomplete cleaning) and over-pickling (acid attack of the steel surface and excessive acid consumption).

The project represents an important step forward, as it has allowed, for the first time, to design, test and successfully implement an on-line under-pickling sensor. The development was carried out in partnership with an equipment builder, fully involved in the project. The system is in continuous operation on one line at the beneficiary, with good performance in terms of availability, sensitivity and robustness; further deployment is still going on. The use of the sensor results in a productivity increase, as there is no need to re-process the coils again.

Concerning over-pickling, another detection system was developed, relying on a hydrogen-based sensor. It proved to be very efficient as hydrogen measurements can detect over-pickling at a level hardly visible for line inspectors. In addition, the sensor, able to resist to harsh line conditions, is also useful for monitoring H_2 levels in critical areas, and thus helps preventing fire on the line and the subsequent idling of the line. The use of the over-pickling sensor has resulted in an increase of the iron yield and a decrease of the consumption of acid. In addition it is considered to contribute to prevent hydrogen evolution and possible line stoppage for safety reasons. It can result in huge

benefits, however difficult to estimate. The risk of fire in pickling lines deserves a special attention, as it is relatively frequent. The over-pickling sensor can be used as a fire protection system.

Benefit of the project HIGHPICK:

The use of the under-pickling sensor leads to an estimated productivity increase of 1 %. At a level of 1 Mt/y, the extra production reaches 10 000 t/y. With an average pickling operation cost of about 30 €/t, the benefit can be evaluated at 0.3 M€/y/line.

The benefit due to avoiding fire in the pickling line has been evaluated, considering that the sensor prevents the occurrence of one fire over 10 years; the idling of the line is estimated at one month. The corresponding benefit for one line is estimated around 0.25 M€/y.

The success in the development of sensors has led the equipment builders to transform the current tools into robust and reliable systems, well adapted to the industrial conditions; the project has opened the way to market developments for the concerned European builders, not only in the Steel industry, but also for other metal pickling processes or aqueous surface treatments.

As there are more than 100 continuous pickling lines in the European Steel industry, the projects represents a huge potential benefit associated with the implementation of the under-pickling and over-pickling sensors.

Finally, additional benefits must be mentioned in the field of safety and working conditions. Indeed the pickling process involves hot and concentrated acid, and possible hydrogen emissions represent a risk for the workers. Reducing the excess acid consumption and preventing the hydrogen emissions clearly improves the safety at work.

6.1.3 Energy, Raw Materials savings

- Real-time intelligent diagnosis and optimisation of reheating furnace performance (SMARTFIRE)

The reheating process before hot rolling aims at heating semi-products (slabs, billets or blooms) to a target mean temperature, with acceptable variation through their cross section and minimal variation along their length. The energy consumption of reheating furnaces, depending on the type of furnaces is a key factor for the economics of a steel plant, both for integrated and EAF-based plants. Modern reheating furnaces are often equipped with closed-loop controls and supervision devices. However there are only few continuous and dynamic measurements of the performance of a furnace, so that inefficient operations or unexpected deviations are identified well after the event, leading to reactive actions only. The project succeeded in developing first a flame analysis system capable of continuously assessing the burner operating parameters and then an advanced furnace diagnosis system, based on modelling work using the flame analysis data. The system was implemented in 4 different reheating furnaces belonging to the project partners. It offered thus excellent opportunities to cover a wide variety of equipments and reheating processes (slabs, billets, and pipes), giving broader applicability to flame analysis and advanced diagnosis. In all cases the system proved very efficient for the furnace performance assessment: significant improvements were noticed

in terms of discharge temperature hitting ratio, better temperature profile, productivity increase, decrease of energy consumption in the range 1 to 3 % and reduction of scale formation by around 4 %. The on-line applications for supervising the furnace performance were judged efficient in fault prediction and prevention, allowing thus better reliability for the reheating furnace and the hot strip mill.

In addition, the acquired knowledge on the flame combustion and the improved monitoring of the burner has allowed to reduce the NO_x emissions.

Finally the expertise developed with the flame monitoring system may be of interest also for the reheating furnace suppliers, and more generally for boiler or power plant industries as well.

Benefit of the project SMARTFIRE:

Considering an average gain of 2 %, the net energy savings at the level of the beneficiaries (7 Mt of hot rolled coils) can be estimated around 210 000 GJ/y, equivalent to a benefit of 2.1 M€/y or 0.3 €/t.

The improvement of scale yield of around 4 % would represent a gain of 2 800 t/y of scale at the level of beneficiaries. This is a loss of iron for the sinter plant. However it is an extra production of 2 000 t/y of hot rolled coil.

6.1.4 New Market Shares

The European steel industry is facing severe challenges regarding the competition with other materials (aluminium, wood, concrete, composites, polymers …). The approach pursued by the steel industry for maintaining and strengthening its market shares has been to develop more sophisticated advanced steels, meeting more closely, or even anticipating, the needs of the customers. Close partnerships have been developed with the steel users (e.g. carmakers for automotive steels or designers and architects for construction steels) in order to get the right knowledge of the real needs of the users, and to be involved, as early as possible, in the design of new goods. Accordingly, the steel producers not only provide steel products but offer steel solutions taking the full benefit of the outstanding properties of steel, one of them being its easy and almost infinite recyclability.

Two examples are taken in the field of steel for the automotive market and steel for the construction market.

- Strain hardening behaviour of modern lightweight steels (STRAINHARD)

The carmakers have been struggling for a long time for reducing the weight of the cars, in order to reach the target of CO_2 emissions aimed at 90 g_{CO2}/km.

Advanced High Strength Steels (AHSS) represent an efficient solution to significantly reduce the weight of the car body and to contribute to lightweight objectives.

Relying on a comprehensive understanding of the microstructure of the AHSS (DP, TRIP, TWIP, LIP…), the project has delivered practical solutions for achieving, simultaneously, a very high strength and good forming, toughness and elongation properties. It results from a detailed knowledge of the strain hardening mechanisms, in relation with the microstructure. The findings have been implemented in Finite Element models capable of predicting the microstructure and the mechanical properties, which proved

very useful for reducing the time needed for the design of new products.

The use of high resistance-high formability steels makes the stamping process easier, so that more complex steel parts can easily be manufactured, reducing thus the number of parts in the car body. Significant cost savings are obtained at the level of the steel users.

The AHSS represent a leap forward and a very credible alternative to the use of aluminium in the car body. The mass production of these steels, on existing lines, guarantees sound economic conditions and profitability.

It can be estimated that about 30 % of the car body-in-white requires complex parts, representing around 200 kg per car, or 3.4 Mt_{steel} /y, at the European level. If there had been no progress on the forming properties of AHSS, most probably steel would have been partly replaced by aluminium. We can assume that 100 kg steel would have been driven away by aluminium, and the remaining steel would have been lower grade "commodity" steels.

The development of AHSS has also induced benefits in the conservation of resources (raw materials, energy, water…).

At this stage, it is worth mentioning the impact of the use of AHSS on the fuel consumption of the cars. It is commonly accepted that reducing the car weight by 100 kg leads to a decrease of fuel consumption in the range 0.4 - 0.6 l/100km, and of CO_2 emissions of about 12 g_{CO2}/km.

In conclusion, this project has strongly contributed to maintain and even develop the position of steel in the car design, including electric cars, in competition with alternative materials, like aluminium or polymers. In addition the RFCS projects dedicated to the development of AHSS have initiated and fostered large internal efforts in the Steel companies for industrialising the production of AHSS. This has helped maintaining the global European competitiveness for the steel industry, with significant market shares for the most advanced steels, and the car industry, which has the leadership in low fuel consumption.

Important Note: It must be noticed that the above quantitative benefits are relying on the European car production during the course of the project (around 17 millions/y). After the crisis, the automotive market has strongly shrunk and has not yet recovered the pre-crisis level.

Benefit of the project STAINHARD:

Taking into account a difference of margin of about 20 to 50 €/t between AHSS and commodity steels, the total loss for the European steel sector could be evaluated in the range 34 to 85 M€/y, if aluminium would have replaced steel in car bodies.

In addition, it is considered that the use of AHSS for the complex parts of the car body generated a steel saving in the range 10 to 20 %, as compared to more traditional steels. This represents a total saving of about 0.5 Mt_{steel}/y at the European level.

In addition, this results in a potential fuel saving of 0.4 Mt/y and a potential reduction of CO_2 emissions by 1.2 Mt/y.

- Large web openings for service integration in composite floors (LWO, LWO+)

In the field of product development for the construction market, the major challenge is to improve the efficiency of steel structures against the ones in concrete, the dominant competitor, and, to a lesser extent, against wood and polymers.

The project has resulted in the development of new innovative structural steel components, based on hot rolled H-beams, for application in single or multi-storey industrial buildings construction.

The process for fabricating more or less complicated sections of cellular beams, with precise shape openings, has been established and validated, relying on modern flame-cutting machines. Compared to traditional steel structures, cellular structures result in lower floor depths and longer span combined with lower weight. With the possibility of producing new elegant opening shapes in the flange, these beams were appreciated by architects because they add lightness and aesthetics to the visible structure.

Beside the technical achievements, special effort has been dedicated to the valorisation of the new product among designers and architects, by providing comprehensive design guides and pre-design aids, to be downloaded from the web site.

Benefit of the project LWO:

European Large Web Opening beams are mainly produced by 2 companies, in Luxemburg and UK, which have developed the market shares. The yearly output for those beams is estimated at 12 000 t/y. Assuming an extra margin of 100 €/t for the production and fabrication, as compared to classical hot rolled beams, the total benefit generated can be evaluated around 1.2 M€/y, for the 2 companies.

6.2 Environmental Benefit

The control of environment in and around the work place is a key objective of the RFCS programme, and environmental issues are addressed by several projects. Even though environment is a transversal topic involving all the production steps in the Coal and Steel sectors, the most severe problems are concentrated in the upstream part of the steel production: harmful gaseous emissions, green house gas, dusts, and ultra-fine particles.

In this field, most of the projects dealing with process improvements or innovations also address the impact of those modifications on the environmental footprint of the process.

More specifically in the Steel sector, the breakthrough ULCOS project gathers all efforts for decreasing the CO_2 emissions in steelmaking. Starting from a large span of process candidates, the project has succeeded in selecting the 4 most promising solutions to achieve the CO_2 reduction objectives. They encompass short, medium and very long term actions. The proof-of-concept of those solutions has been established and large efforts are presently dedicated to evaluate their performance. This is especially the case for the top gas recycling blast furnace process, involving CO_2 capture and sequestration, for which an industrial demonstrator is under development, and the smelting-reduction HISARNA process, currently investigated at the pilot scale. In addition, there are highly innovative and long-term research projects going on.

- Development & experimental validation of mathematical modelling methods for oxy-fuel combustion for CO_2 capture in large power plants (OXYMOD)

The oxy-fuel combustion is considered as an interesting technology for the capture of CO_2 emissions from power plants, and thus very promising for the promotion of the use of coal as a clean energy source.

The project was successful in developing the necessary predictive models and tools to give confidence in the design of the oxy-fuel process. The presence of different burner manufacturers in the project consortium made possible the validation of the models in a large variety of burners at different scales from 30 to 250 MW. Thus the design of a boiler for oxy-fuel can be undertaken with a lower margin on the performance. It leads to a benefit in the thermal and cycle efficiency, and in the plant availability. In a green site plant the improved design models allow to reduce the capital expenditure for the boiler.

Finally this project has contributed to establish the feasibility of the oxy-fuel burner for reducing the CO_2 emissions from the power plants. Several applications have been carried out by the industrial partners of the project.

Benefit of the project OXYMOD:

It has been demonstrated that a classical oxy-fuel burner firing bituminous coal (40 MW) achieves a 50 % reduction of NO_x emissions, as compared to an air firing burner. Similar results were found in the case of firing lignite in a pilot burner.

Reduction by 88 % of the CO_2 emissions in a demo oxy-fuel plant of 250 MW could results in a saving of 11 M€/y, corresponding to the avoidance cost of CO_2 , with CO_2 capture and sequestration.

- Emissions reduction through analysis, modelling and control (ERAMAC)

The project addressed the problem of fugitive and stationary emission of Volatile Organic Compounds (VOC), Semi Volatile Organic Compounds (SVOC), NO_x, SO_2, dusts and particulates from the iron and steelmaking processes. A particular focus was on the coke ovens, the sinter strand, the EAF and the burners.

Different methods were developed first to characterise the difficult to assess diffuse sources at coke oven doors and by-product plants. Real time measurements of benzene, toluene and xylene in ambient air were carried out by improved analytical techniques, like the differential optical absorption spectrometry.

Numerical modelling of reverse dispersion provided an estimate of the release of pollutants. Predictive emission monitoring systems were developed for the characterisation of CO, NO_x, SO_2 emissions in cokemaking and in the EAF.

The new measurement tools proved successful for characterising and monitoring the effluents at very low concentration. The project opened the way for investigating the feasibility of process actuators aiming at the reduction of the emissions.

6.3 Health and Safety, Working Conditions

In the Steel sector, improvement of health, safety and working conditions was an indirect outcome of several projects, whereas in the Coal sector several projects were especially dedicated to these issues.

Many examples can be taken from the steel projects:

- the development of new on-line sensors, in conjunction with supervision models has allowed to create remote and safe working places, away from the most dirty, hot, and harsh zones, like the blast furnace casthouse or tuyere area, the vicinity of travelling hot products in the rolling mill, the acid pickling area, and the surroundings of the liquid zinc pot in the galvanisation shop;
- the extended use of AHSS has resulted in a leap forward regarding the crash resistance of the cars, leading to drastic improvements in the safety of passengers;
- the replacement of classical welding by hybrid laser welding for structures has resulted in the suppression of hazardous welding fumes for the workers;
- the development of prefabricated steel or composite structures in the construction domain has allowed to significantly decrease the risk of accidents on the building site during the construction work.

A typical example of a project dedicated to safety in the Coal sector is presented below.

- Optimization of surveillance, technical equipment and procedures to prevent workers from danger attributed to fire, hazardous or toxic gases, firedamp or climatic conditions (SAFETECH)

Due to long lasting exploitation and natural layout, the European coal mines have to operate in deposits of great depth. According to the depth the methane content of the coal increases as well as the virgin rock temperature. If huge volumes of methane are erratically released, dangerous gas explosions and severe harms to the workforce have to be feared. Therefore accurate monitoring devices and efficient drainage procedures are appropriate measures and will ensure safe working conditions. Additionally the virgin rock temperature in distinct European coal mines has reached more than 60 °C. Climate control, effective cooling procedures and - in case of emergency – climate approved rescue teams are essential prerequisites to facilitate the exploitation of deep coal deposits.

The project dealt with four major tasks, i.e. high sensitive measuring system for analyzing gas, approved devices for preventive maintenance in explosive atmospheres, climate control in working and during rescue operations and gas control in longwall and sublevel caving operations.

The new approach to use semiconductors for early fire detection is very promising especially due to the inherent sensors sensitivity and selectivity. The successful development of a customised infrared camera, a video camera and a monitoring system has delivered very useful tools for inspections in hazardous, not accessible working places.

The investigation of the heat and gas flow in longwall faces gained substantial increase of knowledge to the mine ventilation engineers at deep mining companies. With an improved cooling system mine workers are exposed to less heat stress and are more alert to safety issues.

Another main topic concerned the research works realized in the new environmental chamber at the mines

rescue station in Rawdon, UK. The impact of dehydration and the usage of cooling jackets while executing rescue operations have been examined and led to practical recommendations in emergency procedures. Not only theoretical but also operational studies have dealt with improvements in managing the methane inflow while extracting coal.

It is nearly impossible to calculate the economic benefits of safety related projects. But a strong indication is the accident rate which may be influenced by the combined efforts of operational procedures, changed personal attitude, improved monitoring, better training and other parameters. As an example, in Germany the accident rate in 2003 was counted at about 32 accidents, i.e. 32 accidents per 1 million working hours underground. In 2010 the equivalent accident rate is less than 8 accidents which is a reduction of 75 %. Other European coal mining countries have reported similar improvements.

Benefit of the project SAFETECH:

Dealing with safety and occupational health in deep coal mines the outcomes of the project SAFETECH initiated major improvements and are state of the art nowadays. It is highly probable that RFCS projects, namely the project SAFETECH, have contributed to the most welcome reduction of accidents in underground coal mines.

6.4 Acquisition of new Knowledge

The development of new knowledge is unanimously recognised as the major benefit of all RFCS projects. In the Steel sector, Metallurgy is the core science underlying all the innovations in the field of product development. The RFCS programme offers the unique possibility to support projects especially dedicated to Metallurgy. It allows gathering the most advanced scientific developments for the benefit of the projects aiming at innovative applications of steels for the automotive market and the construction market. Furthermore, this opportunity promotes a network of the most skilled teams in Metallurgy in Europe and attracts them to the steel problematic.

- Mechanical Properties Model for high strength complex microstructures (MEPMO)

The better understanding of the complex relationships between the microstructure and the mechanical properties of high strength steels has opened the way to produce numerical models suitable for the prediction and design of new steels, with enhanced properties. In fact a series of RFCS projects has contributed to enter into the new era of "numerical metallurgy". It must be pointed out however that this concept of "numerical metallurgy" is only efficient and reliable if it rests on sound basic science and physics. This makes the huge difference with local statistical models.

In this project, a suite of models has been developed to predict the microstructure and the mechanical properties of high strength steels, like microalloyed steels and multiphase steels (DP, TRIP, TWIP). Thanks to these models, it has become possible to predict the mechanical properties of finished products during the manufacturing process.

The benefits are obvious: support to the development of new steels,

possible replacement of expensive large scale trials in the plants by calculations, co-development of product and associated process, leading to decrease of the time-to-market, saving of mechanical testing costs, and in-line monitoring of the production for early detection of deviations or better homogenisation of the properties, etc… All these factors contribute to improve the process and product reliability and reduce the rejects or re-routing, with huge economic benefit.

The gained knowledge and the models can also be used in a reverse way, to select the appropriate process conditions to achieve the targeted properties. In such cases there is a high potential time saving for responding to the requests from the customers (shortening of time-to-market).

6.5 Development of Innovative Measurement Systems

- Roll mark detection on the tandem mill (Rollmark)

Roll marks are very tiny defects transferred from the roll to the strip during the cold rolling process. These defects are prohibitive for the quality of the strip.

Before the project was executed, the standard procedure was involving an off-line visual control on a limited surface of the strip, after manual stone brushing.

The pilot project succeeded in developing an automatic inspection system, able to analyse on-line the moving strip (speed over 1200 m/min) surface, directly at the exit of the tandem mill. The detection rate is over 90 %, with a rather limited number of over-detection (about 5 %). This development was carried out in partnership with a European equipment builder, specialised in high sensitive detectors operating at high speed.

In the case of roll mark crisis, the system proved successful in reducing the number of coils affected by the defect, due to more rapid detection. It also provides the operators with an image of the coil surface, with instant image analysis possibilities. This allows a direct identification of the stand and work roll at the origin of the defect, and thus increases the effectiveness of the management of roll changes; consequently, the roll change is just limited to the degraded one. The use of this new inspection system has been considered to provide significant benefits in the improvement of the coil quality management: reduction of the number of down-graded coils, by early detection of the roll mark defect, and decrease of the number of coils inspected on the manual inspection lines.

These benefits can finally be expressed as a reduction of the production cost. It has been considered that the automatic detection of roll marks enables decreasing the number of affected coils by 1, out of 3.

There are obviously additional benefits, the quantification of which would require a detailed analysis of the local situation. Potential benefits lie in the roll management: reduction of the line stops for roll change, increase of the roll life time, and reduction of the roll grinding cost. Furthermore, the detection system could also be implemented at the temper mill, to detect periodic defects generated by this mill.

Benefit of the project ROLLMARK:

For a typical cold rolling mill (1.2 Mt/y), the rate of roll mark defects has been decreased from 0.45 % to 0.30 %, corresponding to 90 coils/y (1 800 t/y). The loss of coils being evaluated at 100 €/t, the project leads thus to a saving of 0.180 M€/y for one mill. In addition, the saved coils escape from the manual inspection (average cost of 20 €/t), which adds a further cost saving of 36 k€/y. The total benefit of the project at the beneficiary level is roughly estimated at 0.220 M€/y for one mill.

- Development of a waviness measurement of coated steels (Wavimeter)

Surface waviness is a key factor controlling the surface quality of galvanised and painted steel sheets mostly used in the automotive industry. Waviness on the steel sheet surface leads to waviness in the topcoat of the painted sheet ("orange peel defect"). This defect is highly undesirable, as it impairs the optical appearance of the sheet, and the customer interprets it as a bad paint quality. Car makers are very sensitive to the waviness defects, but there is no unique and accepted set of parameters to characterise waviness, and each of them uses its own characterisation method. The first prerequisite for controlling the waviness with some chance of success is obviously to measure it.

The project, relying on a basic understanding of the waviness phenomena gathered in a previous RFCS project, has succeeded in conceiving and developing a continuous waviness measurement system, based on microscopic observations and triangulation. A prototype has been constructed and validated at industrial scale on moving product.

For the first time it has become possible to quantify on-line the degree of waviness of the strip. It enables the steelmaker to detect any degradation of waviness, to identify and understand the cause and to launch the corrective actions without delay. The response time is much quicker than with the previous method, involving off line manual measurement on a sheet sampled on the line. The results were considered successful enough to launch the industrialisation of the sensor with a European equipment builder, in the frame of a new RFCS Pilot project.

Furthermore, other applications of the wavimeter system can be envisaged in other industries, like paper or non ferrous metals. This would open the door to new markets, in Europe and outside, for the equipment builder. In a first step, it is considered that a market volume of 30 equipments could be realistic.

Benefit of the project Wavimeter:

The pay-back of the project has been evaluated as a reduction of the number of downgraded coils and a decrease (potentially suppression) of the manual control on dedicated inspection lines. The plant manager of the industrial line involved has evaluated the benefit at 0.1 M€/y for one hot dip galvanisation line.

6.6 Promotion of the Use of Coal and Steel

According to the Council Decisions, the RFCS Programme shall support the competitiveness of the Community sectors related to the Coal and Steel industry. Several projects are specifically dedicated to the enhancement of the use of coal and steel by the customers. Their aim is to develop new products to cope with the ever growing requirements of the

customers or to adapt the product properties in order to facilitate the customer's processes for using coal and steel.

This requires a good degree of intimacy between producers and customers, and therefore many of those projects are carried out in partnership with the users, especially in the Steel sector. The projects belonging to the TGS8 (product development for the construction market) are exemplary in that way: beside the technical issues these projects generally comprise a promotion part, providing the customer with all needed information and tools (guide lines, user's guides, and software) making easier the use of steel for their purpose. A similar approach is conducted in the field of product development for the automotive market, where long term partnerships are prevailing between steelmakers and carmakers. The project described below represents a good example of the promotion of steel in the construction market.

- Fire Safety of steel structures (cluster of 6 projects: FIRESAFETY)

Fire is the biggest single handicap for the utilisation of steel in building construction. Up until the end of the 20th century, fire safety of building structures was checked by applying the concept of "standard fire", to individual structural components (according to ISO), whose "time to collapse" was determined. Although this method has been applied all over Europe, it has no relation with real fire conditions, as it does not take into account the real temperature development during the fire and it only considers individual components and not the building as a whole. The conventional ISO approach revealed very unfavourable for steel, and very expensive prescribed solutions were in the past the only way to ensure fire resistance of steel buildings.

A series of RFCS projects allowed to develop the innovative "natural fire safety concept" (NFSC), based on the determination of data for the fire progress calculation methods, the definition of model scenarios for different types of buildings and the simulation of the behaviour of the whole structure subjected to fire. As a consequence, the protection of the structure and the protection of the people staying or working inside the building were analysed and quantified in a scientific way, leading to better fire safety. A considerable amount of new knowledge regarding material properties, fire development, fire resistance of materials, has been acquired and valorised during the projects.

During the period 2003-2010, the detailed and customised solutions have been developed and optimised. In addition, a large effort was also dedicated to introduce the NFSC concept and the associated expertise among the designers and architects. The projects succeeded in introducing the NFSC into the Eurocodes and in 17 Eurocode National Annexes, covering the major European countries.

In parallel, large efforts have been dedicated to provide training and educational material, like design guidance tools, design software and calculation tools, to be downloaded from the web site, for the ease of use of the NFSC by the engineering offices and contractors. A network of consulting engineers, involving design offices in 15 European countries, has been established, providing expertise and experience in the field of structural design in case of fire.

Benefit of the projects FIRESAFETY:

The implementation and dissemination of the Natural Fire Safety Concept (NFSC) in Europe has clearly contributed to increase the market share of steel in building and construction. According to the NFSC network, a total of about 100 000 t of steel has been used in Europe through the design with NFSC, during the period 2008-2010.

7. Estimation of the Overall Potential Benefit for the Beneficiaries and the European Coal and Steel Sectors

Among the 46 projects or clusters of projects selected for a comprehensive in-depth assessment, aiming especially at the evaluation of the quantitative benefits, 23 were identified as providing the most direct and non-ambiguous financial benefits. It does not mean that all other projects did not deliver financial benefit at all. Their benefits were just less straightforward to establish, or sometimes mostly consisted in knowledge development or long term benefits. Considering only those 23 projects leads thus to a very conservative approach for assessing the quantitative benefits of the RFCS Programme.

Based on the facts and figures provided by the project coordinators and industrial partners regarding the benefits at the level of the beneficiaries, an estimation of the global benefit for the Sectors was established. This estimation relies on the appraisal of the likelihood of dissemination and implementation of the projects results all over the Sectors. The multiplier for the extrapolation results from a reasonable estimation of the number of plants and mines or tonnages which could take benefit from the project results. The financial benefit for the Sectors can therefore only be considered just as a potential benefit. This method of calculation deliberately minimises the effects of the RFCS projects insofar as it only takes into account the benefits of the 23 projects providing the most obvious and straightforward benefits.

The methodology and assumptions leading to the extrapolation of benefits to the Sectors are shortly described below, for the 23 projects under consideration.

7.1 Coal Mining, Conversion and Power Plants

- New mechanisation and automation of longwall equipment (NEMAEQ)

The project NEMAEQ aimed at increasing the productivity at the longwall face and reducing the production costs.

The potential benefit may be assumed by following considerations : the automated shearer developed in this project requires only one driver instead of two; assuming three shifts a day, 30 applicable longwalls in the EU and 35 000 €/y full cost of the shearer driver, this accounts for a potential benefit of 3,15 M€ /y.

Regarding productivity increase, the following assumptions are set: the mentioned 30 applicable longwalls have a production of 0.5 Mt/y, (a very conservative figure, as 1 Mt/y is gained in several longwalls), the production costs at the longwall are estimated at 30 €/t, the average productivity increase should be 20 % (note that RAG has reported up to 55 %). Due to the productivity increase, a cost reduction of 10 % can be assumed, leading to a potential benefit of 45 M€/y.

- Improving environmental control and battery life through integrated monitoring systems (IMPECABL)

The project IMPECABL successfully gained to reduce environmental emissions from EU coking plants and to prolong the life and productivity rates

of existing coke plants. Most existing coking plants in the European Community were designed for an expected life of 20 to 25 years, but with regards to the foreseen demand the steel industry aims at prolonging the life to a term of 40 to 50 years. The techniques developed in the project IMPECABL provide the plant management with a range of investigative and monitoring tools for early identification of problems in older coking plants.

In Europe the production of coke in 2010 was about 43 Mt, with an operational cost of 60 €/t. Capital cost accounts for 25 % of that amount. Prolonging the life of the oven batteries due to the findings of the RFCS project will reduce the capital cost by 10 %. Assuming, that only 5 % is applicable, as maintenance will increase, a final cost reduction of 0.75 €/t can be estimated. In summary the potential benefit amounts to 32.25 M€/y at the Sector level.

- More efficient cleaning concepts for stepping up availability of lignite-fired power plants (LIGPOWER)

There is strong interest from the power generation community to apply suitable cleaning technologies for enhancing availability of coal-fired power plants. At the beneficiary's level, the use of efficient cleaning facilities results in an increase of plant availability by 1 %, leading to a benefit of 1 M€/y for a 600 MW unit. Considering that three units can be concerned in Europe during the period covered by the assessment, the potential benefit at the Sector level is evaluated at 3 M€/y.

In addition, the benefit from the avoidance of wrong investment is estimated at 10 M€.

- Circulating Fluidized Bed combustion for coal-fired power plants (CFB800)

Promising technologies, such as the Circulating Fluidized Bed combustion (CFB) technology, are considered very important for the increase of efficiency in power generation and decrease of emissions. The CFB800 project aimed to scaling up design for CFB technology to size of 800 MWe with a net efficiency of 45 %.

It is estimated that 0.2 Mt of CO_2 can be avoided per year, by using 5 % biomass in the circulating fluidised bed combustion. This corresponds to a benefit of 1.6 M€/y for the CO_2 avoided, assuming a cost of 8 €/t of CO_2.

In addition, saving cost of 4.7% for the beneficiary can be achieved as result of using a ratio of 80/20 coal/petcoke instead of 100 % coal in CFB. The potential benefit for one 800 MW power plant can be estimated at 7.4 M€/y, resulting from a 4.7 % reduction of the 158 M€/y operational cost.

7.2 Steel Process development

- Ironmaking

- Enhanced blast furnace operation and service life by improved monitoring and control of the hearth and blast furnace uniformity

The project has provided various process control systems and methodologies for extending the campaign life of the blast furnace and achieving uniform operation.

The cost reduction due to the prolongation of the blast furnace service life has been evaluated by the beneficiaries at 5 % of relining + stoppage cost, or about 5 M€/BF.

At the European level, on average, 6 relinings per year have taken place during the period of time; assuming that 50 % of the relined blast furnaces have benefited from the technology, the potential cost reduction at the Sector level is 15 M€/y.

The better management of liquid level in the hearth has allowed a coke saving evaluated at about 7 kg/$t_{hot\ metal}$ by the beneficiaries.

At the Sector level, considering an average hot metal production of 100 Mt/y, the potential coke savings is thus estimated at about 0.7 Mt_{Coke}/y; if 60 % of the blast furnaces are fully concerned with the improvements, the potential benefit is about 126 M€/y.

- Short term CO2 mitigation for steelmaking (SHOCOM)

The new technology proposed in the frame of the project allows a net coke saving of 20 kg/$t_{hot\ metal}$, leading to a reduction of CO_2 emissions by 180 kg/$t_{hot\ metal}$, without additional investment cost.

As the technology is quite new, we consider that one medium size blast furnace (1 Mt/y) could be equiped during the period of time. The potential cost saving is evaluated at 6 M€/y, without taking into account the financial impact of the reduction of the CO_2 emissions.

- Steelmaking and Casting

- Application of direct optical temperature measurement in steel-making process (DOT-Application)

The use of the newly developed on-line temperature measurement system in the BOF converter allows to reduce the number of re-blows, leading to an increase of liquid steel production by 1.8 %, and a reduction of oxygen consumption by 2.7 m^3/ $t_{hot\ metal}$. The total benefit has been evaluated at 3.9 M€/converter/y.

As there are other technologies available, we assume that about one third of the 94 European BOF converters could effectively take benefit from this new measuring technique. The corresponding potential benefit for the Sector is evaluated at 120 M€/y.

This evaluation is quite conservative, as it does not take into account the potential benefit for other steelmaking vessels, like EAF and AOD furnaces.

- Enhanced steel product quality & productivity by improved flux performance in the mould through optimising the multiphase flow conditions (FLUXFLOW)

The optimisation of the behaviour of casting powders to avoid flux entrapment results in an increase of productivity and a decrease of defects occurrence.

For long and flat products, an increase of the casting speed by 1 % or productivity by 0.5 % has been observed. The production cost is reduced by about 0.1 €/t. In addition, for long and flat products, a 3 to 4 % reduction of the powder inclusions defects, which affect 2 % of the production, has been observed. The corresponding cost reduction is estimated at 0.02 €/t.

Assuming that 75 % of the continuous cast steel production in Europe (170 Mt/y) is concerned by the improvement of the casting powders for long and flat products, the potential benefit is evaluated at about 16 M€/y.

- New strategies for clogging prevention for improved productivity and steel quality (CLOGGING)

The implementation of the techniques and recommendations to avoid nozzle clogging in continuous casting has increased the productivity of a bloom/billet caster of one beneficiary by about 12 %. This had a positive impact on the fixed costs of production of the EAF-caster route leading to a cost reduction around 1.5 €/t.

As nozzle clogging is a well known problem in continuous casting, it is assumed that only 25 % of the European production of bloom and billets could be concerned by these new improvements. This would lead to a potential benefit around 26 M€/y.

- ***Hot and Cold Rolling***

- Real-time intelligent diagnostics and optimisation of reheating furnace performance (SMARTFIRE).

The real-time supervision system of the reheating furnace, has been successfully implemented in 4 steel companies, and has resulted in a net energy saving between 1 and 3 % (cost reduction between 0.15 and 0.45 €/t) and a reduction of the amount of scale around 4 %, representing 0.04 % of the reheated production.

The results are considered to be applicable at the European level, for about 70 % of the reheated production (slabs, billets and blooms). The potential benefit is evaluated at 45 M€/y for the energy saving and 7 M€/y for the reduction of the scale amount.

- Roll mark detection on the tandem mill (ROLLMARK)

The development of the new inspection system allows the steelmakers to decrease the production cost by reducing the number of downgraded coils and reduce the number of inspected coils on the manual inspection line.

It has been observed that the number of downgraded coil for rollmarks defects is reduced by 1/3 (typically from 0.45 % to 0.30 %), which represents a saving of 0.18O M€/y for a standard tandem mill (around 1.2 Mt/y). A further saving for not passing through the inspection line is evaluated at 0.036 M€/y/mill. Assuming that 30 tandem mills (out of 48 operated in Europe) are implementing the results of the project, the potential benefit is about 6.5 M€/y at the Sector level.

- Effective work roll cooling (EWRCOOL)

The implementation of new roll cooling technologies, involving high turbulence cooling, has allowed to improve the design of roll cooling for long product mills. It has resulted in an increase by about 15 % of the roll life (cost saving about 0.18 M€/y/mill) and a reduction of the number of roll breakages (cost saving about 0.2 M€/y/roll).

Considering the large variety of situations regarding roll cooling performance in hot rolling mills for long products, a quite conservative approach has be used to evaluate the benefit at the Sector level. Assuming that about 30 long products mills would benefit from the new cooling technology, the potential benefit at the

Sector level is estimated around 11 M€/y.

This technology could further benefit to the slab rolling mill, generating huge cost savings. But this is not taken into account in the present assessment.

- Using asymmetrical rolling for increased production and improved material properties (ASYMMROLL)

The project has provided useful knowledge about the possible impact of asymmetrical rolling on the rolling process itself and on the obtained product properties. However there was no development of the asymmetrical rolling technology in Europe during the period under review.

The findings of the project were applied to better control the ski end or long bow defects in conventional hot strip mill. For one mill, the loss of productivity and quality due to those defects is estimated around 0.7 M€/y. As this result was a secondary outcome of the project, we consider that only 10 % of the 45 European hot strip mills could take benefit from this improvement. The potential benefit of the project would represent about 3.15 M€/y at the European level.

- Finishing and Coating

- Optimised productivity and quality of pickling by on-line control of pickling surface (HIGH-PICK)

The development of new sensors to better control the pickling process has provided 2 types of benefits:

- the detection of under-pickling leads to an increase of productivity estimated at 1 % at one beneficiary; assuming a pickling cost of 30 €/t, the potential benefit at the level of the Sector (100 Mt/y of pickled products) is around 30 M€/y

- the hydrogen detector helps in the prevention of fire on the line, which represents a serious incident requesting stoppage and idling of the line for about one month, on average, according to industrial experience. Assuming that the H_2 sensor allows preventing 1 fire/line over 10 years, representing a production loss of one month, the potential benefit at the European level is estimated at 25 M€/y .

The total potential benefit expected from this project at the Sector level is evaluated at 55 M€/y.

- Development of waviness measurement of coated products (WAVIMETER)

The development of the new sensor, able to characterise on-line the surface waviness of the strips, has a significant impact on the productivity and the cost, by reducing the number of downgraded coils and avoiding additional control on dedicated manual inspection lines. The corresponding benefit is estimated around 0.1 M€/y for each hot dip galvanizing line (HDG).

Considering that 30 HDG lines, with a production of 20 Mt/y (all galvanized products included), representing about one third of the total of European lines, can take benefit from the project, the potential benefit at the Sector level is about 3 M€/y.

- Novel annealing procedures for improving Hot Dip Galvanizing of High Strength steels (NOVANNEAL)

The new annealing procedures proposed in the project have helped to select the best annealing conditions for different grades of high strength steels which were known as difficult to hot dip galvanize. It resulted in a decrease of the number of downgraded coils due to unsatisfactory quality of the zinc coatings. In addition the low H_2 annealing process allowed reducing the consumption of HN_X.

It is considered that 10 % of the DP and TRIP grades (respectively 0.5 and 0.3 Mt/y) are concerned by the new annealing process, and that the rate of downgrading for coating defects is reduced by 3 %. Assuming a cost of coil around 750 €/t for those grades, the potential benefit at the European level can be estimated at about 1.8 M€/y.

7.3 Steel Product development

- Automotive market

Concerning the development of steels for the automotive market, it must be noticed that the following quantitative benefits are based on the European car production registered during the course of the projects (around 17 millions/y).

After the 2009 crisis, the automotive market has strongly shrunk and not yet recovered the pre-crisis level. Today, the market development of AHSS has been slowed down and the potential benefits have evolved accordingly.

- Strain hardening behaviour of modern lightweight steels (STRAINHARD)

The project has opened the way for a new generation of steels, combining high resistance and high formability, which strongly contribute to the objective of decreasing the weight of the car body, while keeping excellent strength properties. These steels (TWIP, LIP) will be used for the most complex parts of the car body, representing about 30 % of the steel used in the car body (or 200 kg/car).

The potential European market for those steels can be evaluated at about 3.4 Mt/y, shared between the most advanced European flat carbon steels producers.

If there had been no development of this new generation of AHSS, one can assume that 100 kg_{steel}/car would have been driven away by other materials, and that the remaining 100 kg would have been made with conventional steels, at lower margin.

Taking into account a difference of margin of 20 €/t to 50 €/t between conventional and new generation steels, on average the potential loss at the European level would have been around 60 M€/y.

- DP grades with improved formability (DP grades)

New developments in the metallurgy of dual phase steels (DP) have induced an increased use in the car body. It is considered that the production of DP steels has been boosted up to about 1.5 Mt/y at the European level, thanks to the relevant projects.

Assuming an extra margin for DP steels ranging from 20 €/t to 50 €/t, the potential benefit at the Sector level can be evaluated, on average, around 50 M€/y.

- Local heat treatment of Ultra High Strength Steels (LOCALHEAT)

The technology of partial hardening by local heat treatment, developed in the project, has allowed significant weight reduction (10 to 20 %) for some parts of the car body, as compared to the classical technology involving hot forming of HSLA steels.

In the case of the B pillar of the car body it leads to a cost saving of about 2 €/part.

Based on the European car production of 17 M/y and assuming a conservative 20 % of penetration of the new technology, a potential cost saving of about 7 M€/y can be estimated.

- *Construction market*

- Fire safety of steel structures in construction - cluster of 6 projects on the Natural Fire Safety Concept and fire resistance of steel

The Natural Fire Safety Concept (NFSC) developed in the cluster of 6 projects has been implemented in the relevant Eurocodes with due consideration in the national annexes.

The NFSC network partners have evaluated the tonnages of steel involved in European projects through the design with NFSC. Considering the 3 years from 2008 to 2010, a total of approximately 100 000 t of steel were used. Assuming a margin of 100 €/t for production and fabrication, this figure leads to a total margin of 10 M€ over the considered period of 3 years for the European steel sector.

The Natural Fire concept also allows steel material to be used in structures where previous building regulations based on the ISO approach did not allow its use, for instance steel structures for open car parks in France.

Sales figures (from ArcelorMittal) in the year 2009 amounted to the use of 6900t of steel sections in open car parks in France. Assuming a margin of 100 €/t for production and fabrication, this new application alone generated a total margin of 0.69 M€ in the considered year for ArcelorMittal.

- New products based on hot-rolled H-sections: Large web openings (LWO) for service integration in composite floors (LWO+) and Prefabricated composite beams based on innovative shear transmission (Preco-Beam)

LWO beams are fabricated from hot-rolled wide flange H-beams with higher margins than conventional standard H-beams. The 2 major European producers of LWO beam are in Luxemburg and UK, with estimated outputs of 3000 and 9000 t respectively. Assuming a margin of 100 €/t for production and fabrication, the total benefit generated amounts to 1.2 M€/y for the 2 producers alone.

During the short period of time since the Preco-Beam technology is available for bridge construction, a total of 9 railway bridges have been achieved with this technology in Europe, involving about 1500 t of high-strength wide flange H-beams. Assuming here a margin of 150 €/t, the potential benefit amounts to about 0.2 M€/y.

- Human induced vibration of steel structures (Synpex, Hivoss)

There is a huge interest from the design community to use modern high strength steel for lightweight structures, in bridge and building floors construction. It is reflected by the increasing number of downloads of the Hivoss documents from the web site.

It is difficult to quantify the real market generated by the project. Using the specific ArcelorMittal assumption for converting the number of downloads in sold tonnages, an average consumption of about 20 000 t can be estimated for floor construction and 22 000 t for bridge applications, over the 3 years period 2009-2011. Assuming a 100 €/t margin for production and fabrication of the beams for the floor construction and a 150 €/t margin for the bridge applications, the total potential benefit is evaluated at 5.3 M€ for the Steel sector over the 3 years period.

- Facilitating Market Development for Sections in Industrial Halls and Low-rise Buildings (SECHALO)

The Accompanying Measures project resulted in a "Best practice design guide" for the use of hot-rolled steel sections in industrial halls and low-rise multi-storey buildings.

It is rather difficult to quantify the impact of the project on the consumption for standard long steel sections in the considered application fields. It can be estimated, according to the interest of designers, as reflected by the amount of download of the design guide. Using the specific ArcelorMittal assumption for converting the number of downloads in sold tonnages, it was considered that the steel consumption amounts 32000 t/y. Considering a margin of 100 €/t for the production and fabrication, it leads to potential benefit of 3.2 M€/y for the Steel Sector.

7.4 Overall potential benefit for the Beneficiaries and the Coal and Steel Sectors

As previously mentioned, the financial returns generated by the 23 projects under review were evaluated in two steps:

- first the reliable figures provided by the project beneficiaries and industrial partners, resulting from their experience in the implementation of the results in their own plant, allowed to calculate the proven benefits at the beneficiaries level

- secondly, based on those figures and using conservative assumptions for the dissemination of the results beyond the beneficiaries, the potential benefit for the whole Coal and Steel Sectors was estimated.

The relevant figures of the 23 projects were detailed in sections 7.1 to 7.3.

At the level of the beneficiaries, the 23 projects have provided an annual benefit of 103 M€/y. (Table 5). This figure can be considered as totally endorsed by the industrial partners of the projects. It must be pointed out that this benefit does not take into account the additional costs, namely investment, operational or further research cost, which had to be incurred by the companies to effectively achieve those benefits. In fact in this assessment exercise it was deliberately chosen not to take on board these additional costs, because such estimation can only be carried out with enough accuracy after a detailed analysis of the situation of each project in each plant, on a case by case basis.

This annual benefit identified at the level of the beneficiaries can be compared to the corresponding budget of the projects (in total 52.8 M€ over the period of review) or to the RFCS funding (in total 30.9 M€ over the period of review). Accordingly it can be considered that one Euro spent in the project budget has delivered an annual benefit of about 2 Euros/y for the beneficiaries. When referring to the RFCS funding only, one Euro of public funding has resulted in an annual benefit of 3.3 Euros/y for the beneficiaries.

It must be pointed out that the cost of the project has to be spent first, at the start of the project, and that the full financial benefit shows up gradually, after a time lag of some years. In steady state conditions, the annual benefit can be harvested during several years until the effect of the project becomes diluted in the daily operational practice and in the continuous improvement of the plant. This period of time strongly depends on the domain covered by the project and the competitive situation.

At the level of the Coal and Steel Sectors, the 23 projects analysed above have provided an overall annual potential benefit of 684 M€/y, a rounded figure of about 700 M€/y (Table 5).

Again it must be pointed out that this benefit is only potential, as its realisation depends on several factors which are in the hands of the industrial companies of the Sectors, like the relevance and willingness to implement the project results, strongly dependent on the local situation, the associated investment and operational cost, the industrial strategy, the market situation etc. In other words, the RFCS programme is opening the way for the industrial Sectors to harvest this potential benefit, while providing scientific and technological solutions which must then be adapted and fine tuned according to the local conditions, on a case by case basis. Most generally additional cost must be incurred by the industrial companies to implement the results of the projects and get the corresponding benefit.

This annual potential benefit can be compared to the budget of the RFCS projects. In this case the budget to be considered as a reference is the overall budget of all 198 projects under review in the frame of the assessment exercise (in total 308.1 M€ budget or 182.6 M€ RFCS funding), and not only the budget of the 23 projects. Indeed the benefit provided by the most profitable 23 projects resulted not only directly from the findings of those projects but also from the continuous effort in funding all other projects addressing related issues or providing new knowledge or not quantified outcomes. In addition, it must be recalled that the beneficiaries themselves indicated that about 20% of the projects provided no direct economic benefit. This way of calculation has been deliberately selected to warrant a more conservative approach of the assessment.

Accordingly, it can be estimated that, on average, one Euro spent in a RFCS project budget opens the possibility of an annual potential benefit of about 2.2 Euros/y for the Coal and Steel sectors. This ratio is quite similar to the one calculated above on the basis of the real benefits of the 23 projects at the beneficiaries level. Incidentally, this also shows that the extrapolation rules used to estimate the potential benefit at the sector's level were quite consistent and not over-optimistic.

These profitability figures must be considered very carefully and as only indicative, as the benefit is only potential and the additional cost, beyond the project cost, to implement the results are not taken into account.

		Coal	Steel	Total
Projects with calculated financial returns for the beneficiaries	Number	4	19	23
	Project budget (M€)	11.0	41.8	52.8
	RFCS Funding (M€)	6.1	24.8	30.9
Benefits assessed for the beneficiaries	(M€/y)	16.2	86.5	102.7
Projects in the total assessment exercise	Number	32	166	198
	Project budget (M€)	78.0	230.1	308.1
	RFCS Funding (M€)	45.7	136.9	182.6
Potential benefit for the Coal and Steel Sectors	(M€/y)	103	581	684

Table 5. Calculated financial return of the 23 projects for the beneficiaries and potential financial return for the Sectors

The nature of the potential benefits identified for the Coal and Steel Sectors is briefly discussed below.

The reduction of production cost, including energy and raw materials savings, account for slightly less than 50 % of the potential benefit. A significant contribution arises from the improved use of the assets, due to the extension of the life time of coke batteries and blast furnaces. The improvement of productivity is the second important source of benefit, at 34 % of the total (Figure 19). The increase of market shares resulting from the development of new products accounts for about 20 %. This is mostly due to the new steel products for the automotive market and, to a lesser extent, the construction market.

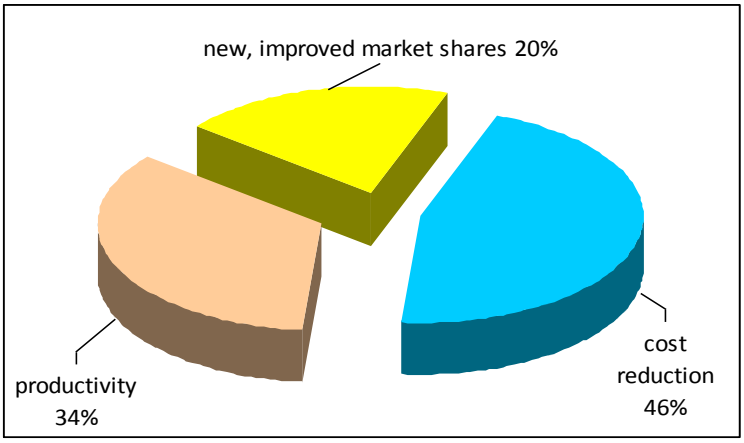

Figure 19. Distribution of the potential benefit of the assessed projects for the Coal and Steel sectors

The respective contributions of the different production areas to the potential benefit are shown in Figure 20. The selected coal projects account for about 15 % of the global potential benefit. In the Steel Sector the potential benefit is almost equally distributed between the four areas. Ironmaking, Steelmaking and Casting account for about 45 % of the total. This is due to a large impact of cost reduction, energy and raw material saving in those areas.

To capture these potential benefits, it is obvious that additional efforts must be pursued at the company level for implementing the relevant technological solutions provided by the RFCS projects.

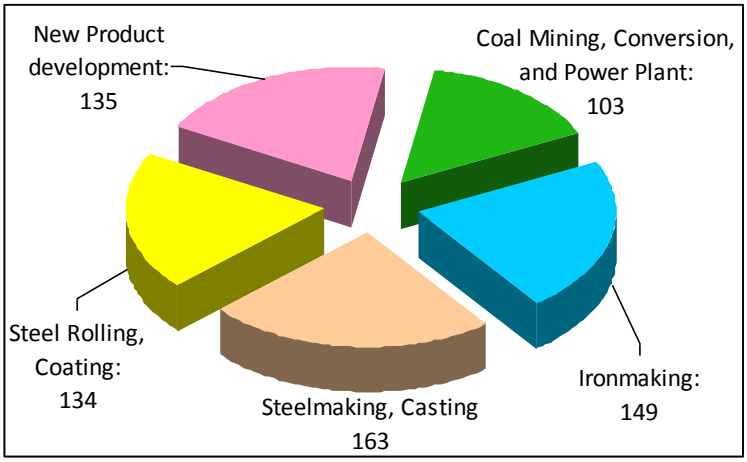

Figure 20. Potential benefit (M€/y) of the assessed projects in the different production areas for the Coal and Steel Sectors.

7.5 Estimation of the accumulated benefit of the projects

R&D is generally considered as a long term investment, and most companies strive to establish the profitability of research projects, using dedicated methodologies. Such an exercise is quite difficult and can only be done on a case by case basis, taking into account local industrial and market conditions. It is out of the scope of the present assessment to present a full cost/benefit analysis of the RFCS programme as a whole.

Nevertheless it has been considered as interesting to develop a rough estimation of the order of magnitude of the potential accumulated benefits generated by the sample of 23 projects for the beneficiaries. A very simple model was used for that purpose, relying o the following simplifying assumptions:

- the projects are starting in year n and are lasting for 3 years
- the R&D cost is equally spent over the 3 years
- the annual benefit of the projects is zero during the first 2 years and is ramping-up over years n+2 (25 % of full benefit) and n+3 (75 % of full benefit)
- the full annual benefit is achieved during 5 more years, and afterwards goes to zero
- the depreciation ratio is taken at 5 %/year.

Deriving from these assumptions, the overall updated accumulated benefit of the 23 projects, corresponding to the annual benefit of 102.7 M€/y, can be estimated at about 400 M€, at the level of the beneficiaries. This figure corresponds to an average multiplying effect of about 8 € benefit for 1 € spent in the project budget. If referring the accumulated benefit to the RFCS funding alone, the multiplier would increase up to about 14.

At this stage it must be pointed out again that different assumptions could have been used to develop this calculation, leading to different results. These figures must therefore be considered very carefully and as only indicative. Furthermore they do not take into account the additional cost, beyond the direct project cost, to implement the results in the industrial practice.

8. Summary of Comments and Validation

8.1 Achievements of the RFCS projects

The high degree of achievements of the RFCS projects objectives according to the four components, technical, scientific, economic, and social, represents a very significant result, considering the level of risk inherent to R&D activities. It reflects the high relevance of the projects as well as the quality of management. Even if the social issues are generally not the prime objective of the projects, it is worth to notice that social achievements are registered for more than 50 % of the selected projects.

The selected RFCS projects show a wide span of achievements: new knowledge, recommendations, new processes and practices, numerical models, new solutions and products, and measuring devices. More than 60 % of the projects are providing numerical models, which represents a quite high rate. It reflects the increasing degree of sophistication of the Coal and Steel industry, with the need for models for understanding and control purposes. A similar comment also applies for the measurement devices, which are provided by around 40 % of the projects.

It is important to point out that these achievements are not only research results. Indeed they can be considered as practically or industrially proven solutions, as the beneficiaries implemented and validated the developments during the course of the project. These new achievements contribute to increase in a continuous way the knowledge base which is shared between all the members of the sector. Moreover this new knowledge is made available to the whole Coal and Steel community.

8.2 Benefits generated by the Projects

8.2.1 Benefits for the beneficiaries and the sectors

In the Coal sector, the increase of knowledge and the dissemination of expertise in the company through training and education are creating the most important value for the projects beneficiaries. The development of new processes and new solutions along with the economic benefit and cost reduction issues are rated very high. This ranking reflects that the RFCS projects contribute to maintaining or increasing the competitiveness of the related industry by providing innovative solutions, with due consideration to economic issues. Environmental improvement and health and safety are also considered among the most important benefits generated by the projects.

At the Coal sector level, the ranking of benefits shows the same trends as at the beneficiaries' level, with Safety and Health achievements being scored even at a higher level. For safety related issues, the networking of partners, fostered by the RFCS programme, represents a valuable source of progress.

In the Steel sector, the increase of knowledge and its dissemination through training and education are considered as the most important benefits generated by the projects at the beneficiaries and sector levels. The development of new or improved processes, new products and new solutions are scored as very important. Indeed innovation in process and the development of new products for the customers are key achievements for ensuring the sustainability of the Steel

sector in the future. The important score attributed to cost related issues highlights the fact that in heavy industries the stress on cost is prevailing, even for innovative products. In the upstream part of the manufacturing routes raw materials and energy savings are highly valued. Health, safety and improved working conditions are addressed in many projects.

8.2.2. Benefits for Society

The RFCS projects positively contribute to the major challenges the European Society is facing to remain sustainable and competitive. The increase of knowledge is considered as the prime benefit. The development of new technologies, new steel products and new applications are recognised to heavily contribute to the European competitiveness in the global market. The conservation of resources represents a significant outcome of the RFCS projects, contributing to the global sustainability of Europe, facing high cost and critical scarcity of raw materials and energy. In addition, the projects are considered to help in improving the health and safety conditions of the people at their working place and the citizen using steel products and goods. Finally, these achievements exert a welcome effect on the security of jobs.

8.2.3 Quantitative assessment of benefits

The quantitative benefits generated by the selected projects can be classified in six major categories:

- the financial returns: cost reduction, productivity increase, energy and raw materials savings, and increase of market shares
- the environmental benefits
- the health and safety issues
- the development of knowledge, including modelling
- the development of innovative applications, including sensors and measuring techniques
- the means for better use of coal and steel.

At the level of beneficiaries, the RFCS projects have provided significant financial returns. Considering only the 23 projects identified as providing the most straightforward quantitative benefits, the annual financial return was evaluated by the coordinators at about 103 M€/y. This annual amount can be compared to the total budget of those 23 projects i.e. 52.8 M€.

The extrapolation of those benefits to the Sectors is not straightforward, as it depends on the degree of dissemination of the project results and the local conditions. Nevertheless, there is a huge potential benefit associated with the deployment of all project results through the Sectors. According to conservative assumptions regarding the roll-out of the results through the Sectors, the potential financial benefit has been estimated at a rounded figure of 700 M€/y. It represents a key aspect contributing to the sustainability and the competitiveness of the Coal and Steel sectors in the European Union.

8.3 Dissemination of the project results

The degree of dissemination of the projects results is very high at the level of the beneficiaries and slightly less, but nevertheless very significant, at the sector level. This emphasises the quality of the technical exchanges between the partners inside the project consortium and the efficient transfer of knowledge inside the Sectors. The networking between specialists, fostered by the active discussions during the regular TG meetings,

certainly contributes to spread out the project results beyond the beneficiaries. The efficiency and swiftness of the transfer could be improved, namely by an increased use of workshops or web sites dedicated to updating the state-of-the-art on focused subjects.

Individual projects led to commercial exploitation at the beneficiaries' level, and more often to a new project. It is useful to combine several projects in a cluster way to solve complex industrial problems. The use of pilot and demonstration projects appears as an appropriate way to complement R&D projects up to the final industrial solution and its exploitation.

This analysis leads to point out the necessity to address the transferability issues during the course of the project, for example by promoting solutions as generic as possible. This is especially relevant for the transfer of models or sensors.

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Abbreviations

AHSS	Advanced High Strength Steel
Beneficiary	Beneficiary of a RFCS project; mostly meant as those beneficiaries questioned in the assessment exercise
BOS, BOF	Basic Oxygen Steelmaking, Basic Oxygen Furnace
CAG	Coal Advisory Group
CC	Continuous Casting process
CCS	Carbon Capture and Storage
COSCO	Coal and Steel Committee
DP steel	Dual Phase steel
ECSC	European Coal and Steel Community (expired in 2002)
EAF	Electric Arc Furnace
ExCo	Expert Committee for the RFCS Monitoring and Assessment exercise
HDG	Hot Dip Galvanisation process
HSS	High Strength Steel
HSLA	High Strength Low Alloy Steel
LQ	Long questionnaire used in the assessment exercise
Mt	Million of tons
M€	Million of Euros
NFSC	Natural Fire Safety Concept
PEM	Particulate Emission
Q+T steel	Quenched and Tempered steel
RFCS	Research Fund for Coal and Steel (successor of ECSC)
RTD, R&D	Research and Technical Development, Research & Development
SAG	Steel Advisory Group
TG	Technical Group of the RFCS Programme
TGS	Technical Group for Steel
TGC	Technical Group for Coal
TRIP steel	Transformation Induced Plasticity steel
TWIP steel	Twinning Induced Plasticity steel
ULCOS	Project "Ultra Low CO_2 emission Steelmaking"
VOC, SVOC	Volatile Organic Compound, Semi-Volatile Organic Compound

Annex

Detailed description of the projects selected for the Assessment Report (Additional file)

The Annex to the Assessment Report is available here.

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The Research Fund for Coal and Steel was established 2002 to support the competitiveness of the European Coal and Steel sectors by supporting research, pilot and demonstration projects.

In accordance with the legal basis of the Research Fund for Coal and Steel (Council Decision 2008/376/EC) the Commission shall carry out an assessment exercise having as purpose to assess the expected benefits from the Research Programme and a report shall be issued by the end of 2013. To this end an Expert Committee was established in 2011 following nominations by the Coal and Steel Advisory Groups in order to assist in this exercise.

This report represents the outcome of work carried out by the Expert Committee until February 2013 and contains the detailed analysis of the 198 projects completed during the period 2003-2010 covering the Coal and Steel sectors.

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