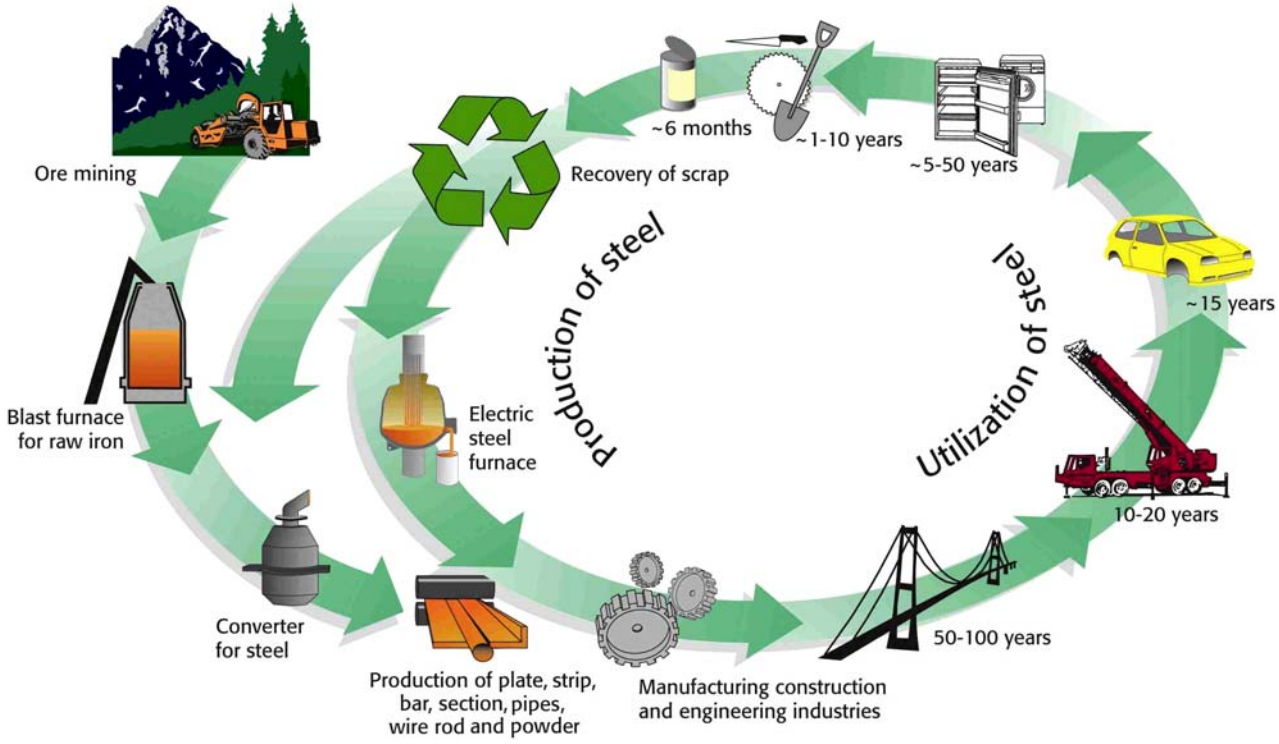
JERNKONTORET

The Steel Eco-Cycle



Programme Plan 2004-2008

Year 2008

MISTRA

Contents

1 The problem and the solution

The Swedish steel industry has successfully developed steel products with high performance and energy-efficient production processes with low waste emissions to the environment. Up till the present time the main issue has been to resolve specific problems, by improving production sub-systems or limited sets of product features. The demands for sustainability – from customers, the public and authorities – are in the future anticipated to become more based on a holistic view, simultaneously focusing on *saving of natural resources and energy* (eco-efficient manufacturing), *safe use* and *recyclables* for applications and products. An integrated research programme with a systems approach is needed to provide the necessary foundation for environmental optimisation of future product and process development.

In today's post-industrial society an important current of the public debate has focused on the potential health and environmental risks associated with industrial activities in general. One can therefore anticipate an increased awareness of environmental issues and caution with respect to potential risks among customers, employees, and regulators. A practical consequence of this debate is that the environmental management in industry will have to be given greater scope in the overall business operations.

Emerging demands for consideration of environmental aspects in product development are likely to be followed by economic instruments and brought back to the manufacturing industry. Examples of this development are the ambitions of the European Commission with regard to an Integrated Product Policy (IPP), and the directives on the end-of-life vehicles (ELVs), waste electrical and electronic equipment (WEEE) and restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS). In its current Environment Policy Review, the Commission give efforts towards a sustainable use of resources high priority. The decoupling of resource related negative impacts from economic growth is seen as the strategy of choice for the next 25 years. In this strategy, a key task is the research, development and promotion of production methods and techniques to encourage eco-efficiency and sustainable use of raw materials and energy. A similar development of environmental policy is seen in Japan, where also legislative means have been applied to promote "green purchasing" in the governmental sector.

It is therefore obvious that we need to upgrade and strengthen our knowledge about how the manufacture and use of products may impact on the environment as well as on human health and safety. It will be particularly important to evaluate the environmental impact at an early stage in the development of products, materials, processes and methods, in order to avoid or minimise unwanted side-effects. This need is especially pronounced for knowledge intensive products like modern, high strength steel grades.

The ability to communicate and evaluate the environmental performance of processes and products in co-operation with customers, regulators and the public will become a determining factor for the business success, economic growth and competitive strength of the steel industry. To accomplish this, there is an urgent need of integrated instruments for the development of new processes, materials and products.

The ultimate goal of the proposed research programme is: **A sustainable manufacture and use of steel**. A sustainable manufacture is here defined as a set of integrated industrial processes that meets the needs of society while maintaining the integrity of ecosystems over a long-term time horizon.

In order to achieve this goal it is evident that a substantial amount of new scientific knowledge and technical know-how must be generated and the collaboration between researchers in different fields must increase. The steel industry is also in urgent need of the services by qualified researchers in environmental science and technology.

The problem areas with regard to sustainability, and in need of further scientific research, have been identified as:

- The consumption of ore, minerals and fossil fuels.
- Scrap metal not returned to the steel industry, thereby preventing recycling.
- Lack of analytical and measurement methods, limiting the potential for classification with regard to alloys and coatings.
- Coatings, e.g. corrosion protection, and surface contamination of scrap.
- Loss of metals to air and water due to lack of effective treatment methods
- Loss of alloys in the residues from the manufacture of steel.
- Waste, which is deposed due to lack of suitable treatment methods
- Big transport flows of raw materials, semi products and finished steel
- Lack of methods for environmental assessment, to be applied in the development of steel grades for use in applications and products.
- Insufficient knowledge of design methods for weight reduction and ease of disassembly.
- Environmental evaluations and call for actions without a sound scientific basis.
- Lack of multidisciplinary know-how and dissemination of information to connect process, materials and product development with economy and environmental issues.

Figure 1 provides a visualisation of the sustainability problem, in form of the currently widening gap between the production of crude steel and the consumption of scrap in the steel industry worldwide. This gap obviously needs to come closer rather than widening to save energy and natural resources.

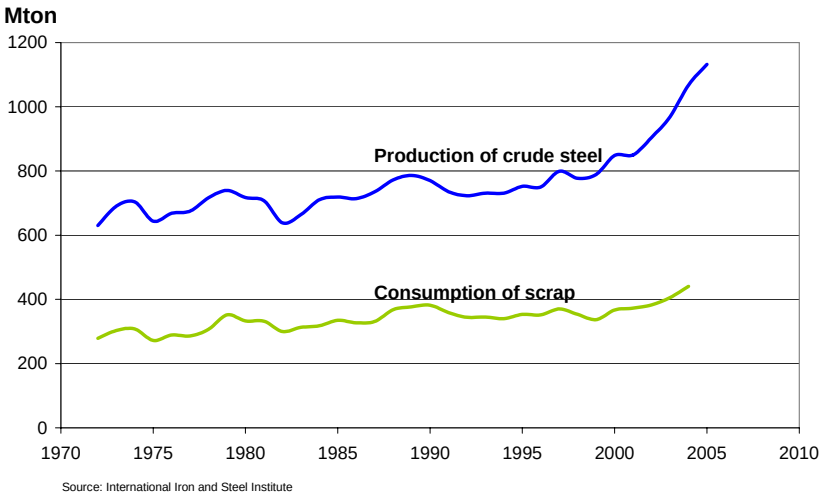


Figure 1: *Production of crude steel and consumption of scrap by the steel industry 1972-2005 (source International Iron and Steel Institute).*

The vision of the proposed research programme is: **Closing the loop in the manufacture and use of steel in the society**. This vision, with a longer time-scale for realisation than the proposed programme, is to guide this research incentive and contribute to a harmony with the societal view on sustainable development and environmental quality objectives.

One primary group of users of the results from the proposed research programme is found in the steel and manufacturing industry. This target group for the acquired knowledge is not only composed by the R&D and environmental departments, but also product design, production, marketing, finance and management. We have the same ambition for crossover in disciplines among the users as for the researchers.

Another key group of users is found among decision makers and regulators in the public sector. An increased insight to possibilities and limitations in the production and manufacturing processes, and potentials for further developments, will improve the quality in the decisions taken.

The third key group of users is the public and other stake holders, and efficient communication of the research findings is thus of utmost importance.

Results from the proposed research programme are anticipated to significantly contribute to saving of natural resources and energy, in the manufacturing and use of steel.

This will be accomplished by:

- Increasing the recycling of scrap metal and optimising the use of alloys in the steel eco-cycle.
- Effectively economising the use of steel in applications and products.

The suggested research programme will also provide:

- Knowledge, criteria and models to evaluate the environmental impact when developing new steel grades, processes and manufacturing technology.
- Knowledge, criteria and models to evaluate the environmental impact in the selection of structural materials, design considerations, use and recycling of applications and products.
- An increased interdisciplinary and multidisciplinary cooperation between the research groups and the users of research results from the programme.
- An increased number of qualified researchers within the environmental field.
- A basis for commercialisation of the research results.

The scientific efforts required to achieve these goals are substantial and will involve a considerable degree of cooperation between traditionally separate fields of academic research. To deliver a successful outcome, the programme management have involved several Swedish universities and research institutes. The research programme will also benefit from the fact that several of the participating research groups have extensive networks of international cooperation.

Projects for inclusion in the research programme have been selected on the following principles:

1. Research projects aiming at a system change or system shift have been given priority over optimisation of present technology

2. Research projects on new steel grades have been given priority in order to achieve a long-term contribution to value-building and competitive strength.
3. Priority has been given to the research projects with the largest potential for providing environmental optimisation in the saving of energy and natural resources over the entire steel eco-cycle.
4. Priority has been given to projects that generate new knowledge and new methodologies.

The individual research projects – within the programme – are organised into three main categories: *Production technology* with focus on materials recycling (from collected scrap to finished steel products), *product design* with focus on materials economisation (from construction materials to deconstruction) and *relevance studies* with focus on environmental values and potential for their realisation (environmental optimisation).

2 Programme deliverables

The programme will result in new concepts for design and production of steel based utilities (products and functions), as well as a more refined methodology for evaluating environmental impact. In the second phase, covering the next four year period, several of these new concepts and methods are anticipated to be developed further into products and services. In Table 1 the deliverables in the first phase are briefly summarised (further details are given in description of each projects).

The full potential for environmental improvements from the proposed programme can be estimated in different ways. The projects related to production technology are estimated to provide feasible technical solutions to reduce the CO_2 emissions from the Swedish steel industry by 1.0 Mton/year and energy consumption by 600 GWh/year at the current production level 2004. The savings potentials for several raw materials are also high. The projects related to product design are expected to achieve technical solutions that may reduce weight in steel structures by 20-25 % (based on previous experience from the car and heavy vehicle industry, and other equipment for transport and cargo handling). Much of the research within the programme is expected to have considerable impact in reducing the release of contaminants into the biosphere.

The projects in the programme will mainly give fundamental information for further testing in pilot plants or demonstration plants. A second research period with this kind of tests is therefore foreseen for some projects.

Table 1: Programme deliverables 2004-2008, briefly summarised

	Recycling	Economising	Relevance studies
Concepts	Classification and sorting of scrap online. Increased use of steel scrap by combined preheating and surface cleaning. Novel processes for slag treatment and metallurgical refining during steel making.	Processing conditions to provide maximum strength and toughness, and improved utilisation of alloy elements.	
Methods	Methods for optimisation of material flows in shredder plants.	Design methodology, rules and guidelines to minimise weight, and to facilitate recovery and recycling.	LCC-tool for environmental profiling of steel production and use. Preference based evaluation of environmental performance.
Know-how	Scientific knowledgebase recovery of steel and the material flows in society. Thermodynamics and kinetics of slag-steel interactions.	Strengthening mechanisms and acceptable combinations of retained elements.	

Results will also be presented at conferences in Sweden and at international scientific meetings, both separately for the different projects and also for the programme as a whole. Publication of interim and final project results in peer-reviewed scientific journals will be encouraged.

We plan to publish the final reports from the programme, the sub-programmes and the individual projects as compendiums. We believe that such a publication will have a lasting value; contribute to the dissemination of information on scientific achievements, serve as a reference for the ‘state-of-the art’ and find use in higher education.

Much of the research within the programme is performed by experienced researchers at the postdoc-level. However, the proposed projects are also anticipated to result in some licentiate and doctoral theses during the first programme period. Licentiate theses are planned to be followed by full doctoral theses during the second programme period.

Deliverables for each project of the programme are specified in enclosed project descriptions

3 Programme structure

The programme work can be divided in two technically oriented sub-programmes (project clusters): **Recycling** and **economising** of materials and energy. **Relevance studies** with a focus on environmental values (environmental optimisation) will run in parallel as the third sub-programme. The relevance studies and other activities will contribute to connect and unite the different projects into a coherent approach.

Sub-programme recycling

The sub-programme recycling includes seven projects which mainly are focused on production technology.

Projects *"Mapping and development of the shredder product steams"* (project 88011) and *"Advanced scrap sorting based on Laser Induced Breakdown Spectroscopy (LIBS)"* (project 88012) will investigate and develop analytical methods and sorting technology in the shredder plants to improve the yield and the quality control of steel scrap. This project has two lead participants: KIMAB and MINPRO. MINPRO mapping product streams to build the necessary scientific knowledge base for an improved technology in shredder plants (project 88011). KIMAB will develop software for an analytical system based on Laser Induced Breakdown Spectroscopy (project 88012).

The project *"Recycling of steel in the society"* (project 88013) is realised by KTH, and will analyse the influence of economical and technical variables on the degree and appearance of the recycling of steel. Historical figures will be used to create a model for the relations governing the recycling. The model will be used for forecasting and analysis of possible future developments.

The project "*Surface cleaning of steel scrap"* (project 88020) will develop methods for simultaneous preheating and surface cleaning of scrap for further use in the steel and foundry sectors. This project has two lead participants: MEFOS and Gjuteriföreningen. MEFOS will develop the process and investigate key operations, and Gjuteriföreningen will perform melting tests with the surface cleaned scrap.

The projects within the category of metallurgical technologies will investigate new slag systems and the potential for increased retention of metal valuables in the steel cycle. This will involve novel processes for slag treatment and metallurgical refining during steel-making. The project has three lead participants: KTH develop steel melting methods for *"Retention, Recovery and recycling of Valuable Metals"*(project 88032), MEFOS develop methods for *"Recovery of vanadium and fully use of slag components in BOF- slag"*(project 88031) and LTU provides knowledge regarding *"Stabilization and reuse of AOD-, EAF, and ladle slag"* (project 88033).

Sub-programme economising

The sub-programme economising includes three projects within the category product design and new steel products.

The projects will develop the use of high strength steel and identify the environmental value in combination with an improvement of production and properties of the steel products. This project has two lead participants, KIMAB and Sperle Consulting AB. KIMAB will develop improved product properties in recycled and high strength steels, together with the production process through *"Improving high strength steels with energy efficient process routes"*(projects 88041) and thruogh*"Optimising Retained Alloy Elements in New Steel Sheet Products"* project 88042). Sperle Consulting AB will develop *"The evironmental value of high strength steel structures"* (project 88044) and validate methods for life- cycle evaluation of environmental impact when advanced high strength steel is used for weight optimization The research package will contribute to attain society's goals for low-emissions and economising with resources and energy for different steel structures.

Sub-programme relevance studies

The sub-programme relevance studies include two projects with focus on environmental optimisation.

The project related to evaluation of environmental values will provide LCC/LCA support for selected projects, assessment methodology and models as well as decision support tools. This project has two lead participants: IVL and University of Kalmar. IVL will develop methodology and models for life-cycle environmental and cost assessments through project *"Methodology- life –cycle costs and environmental impacts"* (project 88051). University of Kalmar will develop methodology for evaluating and integrating preferences from various groups of stakeholders into the environmental decision-making process through project *"Conjoint analysis as a decision tool for evaluation of environmental performance"* (project 88052).

Synthesis, communication and education

Much of the synthesis work is to be accomplished by the relevance studies run in parallel with the two technical sub-programmes, Figure 2. We also intend to organise several arenas and other activities for the project participants to meet, e.g. regular meetings between project managers, a seminar series, conferences, incentives to encourage joint papers and other publications.

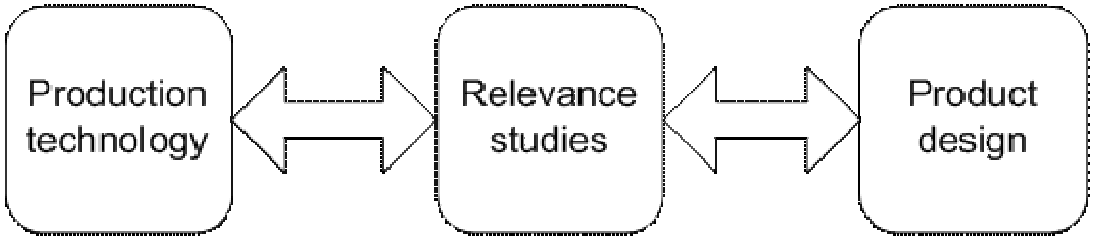


Figure 2: *The relevance studies will contribute methodology and tools to evaluate environmental impact, and are also the "glue" between projects dealing with production technology (recycling) and product design (economising)*

The users have already played a crucial role in developing the programme proposal by an in-depth review of all projects suggested from our first call of proposals in October 2003. Reviewers were selected among managers and senior experts in our member companies to give a comprehensive input on all aspects of the suggested proposals.

The users will continue to interact with the programme, the sub-programmes and each project through the extended network of committees and working-groups within Jernkontoret (Swedish Steel Producers' Association). The members also have direct access to information from ongoing projects through the public and the internal website.

4 Synthesis

A plan for synthesis is being implemented from the project start by the organisation in two sub-programmes with the third, *relevance studies*, being overlaid and specifically assigned to interact and tie the sub-programmes and projects together. The various projects have also been set up with the purpose of improving co-operation between different research organisations and university departments, by joining two or more partners already from the project start. Syntheses will also be a major assignment for the committees and working-groups assigned to the programme.

Participants from the various projects will interact at conferences arrange within the programme framework and joint publishing will be encouraged.

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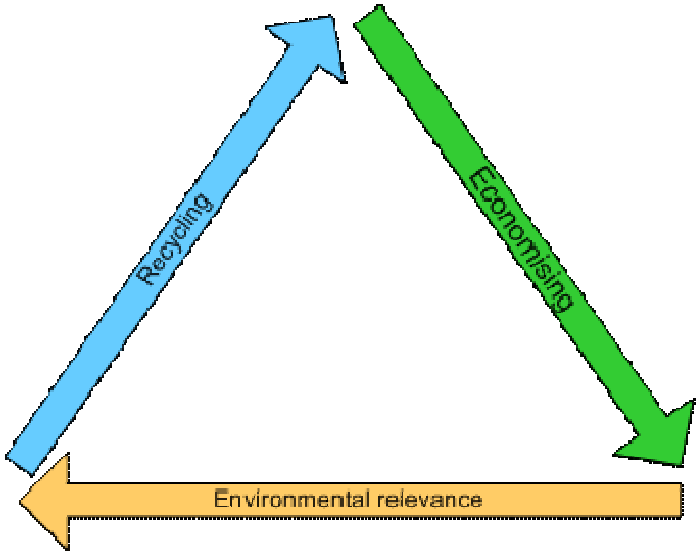

Figure 3: *Synthesis, an iterative process where the sub-programmes contribute to building a common bank of knowledge*

5 Collaboration with researchers

The national and international networks of the involved research groups are extensive. Some examples of the international co-operation are: Eidgenössische Technische Hochschule Zürich, Fraunhofer Institut für Lasertechnik, L'Ecole Polytechnique Fédérale de Lausanne, London School of Economics, Massachusetts Institute of Technology, Queens University (Canada), University of Malaga, University of Tokyo etc.

The different research groups will actively collaborate with other researchers in the Nordic countries, both within academia and industry. All projects will be discussed in project groups with participants from the steel industry, the scrap dealers and other industries.

6 Co-operation and communication with the users

One of the main purposes of the proposed programme is to make the Swedish steel industry more competitive. This research proposal has also been developed with a substantial commitment from the steel industry.

The research programme will be implemented within Jernkontoret's existing framework that has been very successful over many years. The participation of users in the programme and individual project workgroups will ensure a smooth transfer to commercialisation of results. The commitment of steel industry and the scrap dealers in the joint research programmes is already manifested in the high degree of participation in the technical research committees and other programme bodies.

We believe that an eco-efficient manufacture and use of steel is an important part of the future competitiveness, as we already see as emerging trends in Europe and Japan. The users of the research results share this view as demonstrated in their active participation and comments in the project reviewing process. The major portion of the proposed research is focused on method development rather then product development. The programme focus is long-term and commercialisation will thus not come quickly. The organisation of the programme within Jernkontoret will however ensure that the results will be effectively disseminated within the industry.

The results from the programme will be implemented as operational methods and equipment, or demonstration and pilot plants during the second programme period.

7 Communications plan

Programme results will be communicated through an external and an internal website. Programme and project results will be reported as written reports in the Associations report series 'Jernkontorets Forskning', ensuring quick dissemination of results and provide opportunities for feedback from the users. Open conferences and seminars will be arranged in Sweden during the programme period, and results will also be reported at scientific meetings and in international scientific and technical publications.
Furthermore, participants in all project groups and reference groups will be able to follow the programme and the projects continuously through the internal part of the website. Minutes from technical committee meetings and interim technical reports are examples of the documents shared.

8 Programme management

A major task for the operative organisation of the Steel Eco-Cycle is to;

- be a "knowledge bridge" between industry and scientist involved
- synchronise each project research work to the programmes goal
- create a high industry value as a part of the scientific results committed by the programme
- perform an effective platform for fulfilment of the programmes synthesis, deliverables, time schedule and economical limits

The present organisation chart includes;

- Programme board with industry members on CEO level
- Executive and assistant programme director
- Advisory group with the chairmen of research committees
- Four research committees, each leading a group of projects
- Eleven project groups for execution of the detailed research working plan

The project leaders are responsible for the daily scientific leadership of their own projects, but each project is discussed in the project group with participants from the steel industry, scrap dealers and the manufacturing industry. The ongoing deliverables for a group of projects and theirs progress according to time schedule, economy and the goal of the Steel Eco-Cycle programme is govern by respectively research committee.

The organisation of the programme is supported by a strong industrial representation. The steel industry, scrap dealers and the manufacturing industry have appointed a great number of engineers from production, R&D and environmental disciplines, mainly to be members of the eleven project groups.

The experience of the present organisation and a close co-operation, from starting a programme and single projects seems to be a very efficient way for introduction of research results for practical application.

For the actual organisation chart, see Figure 4.

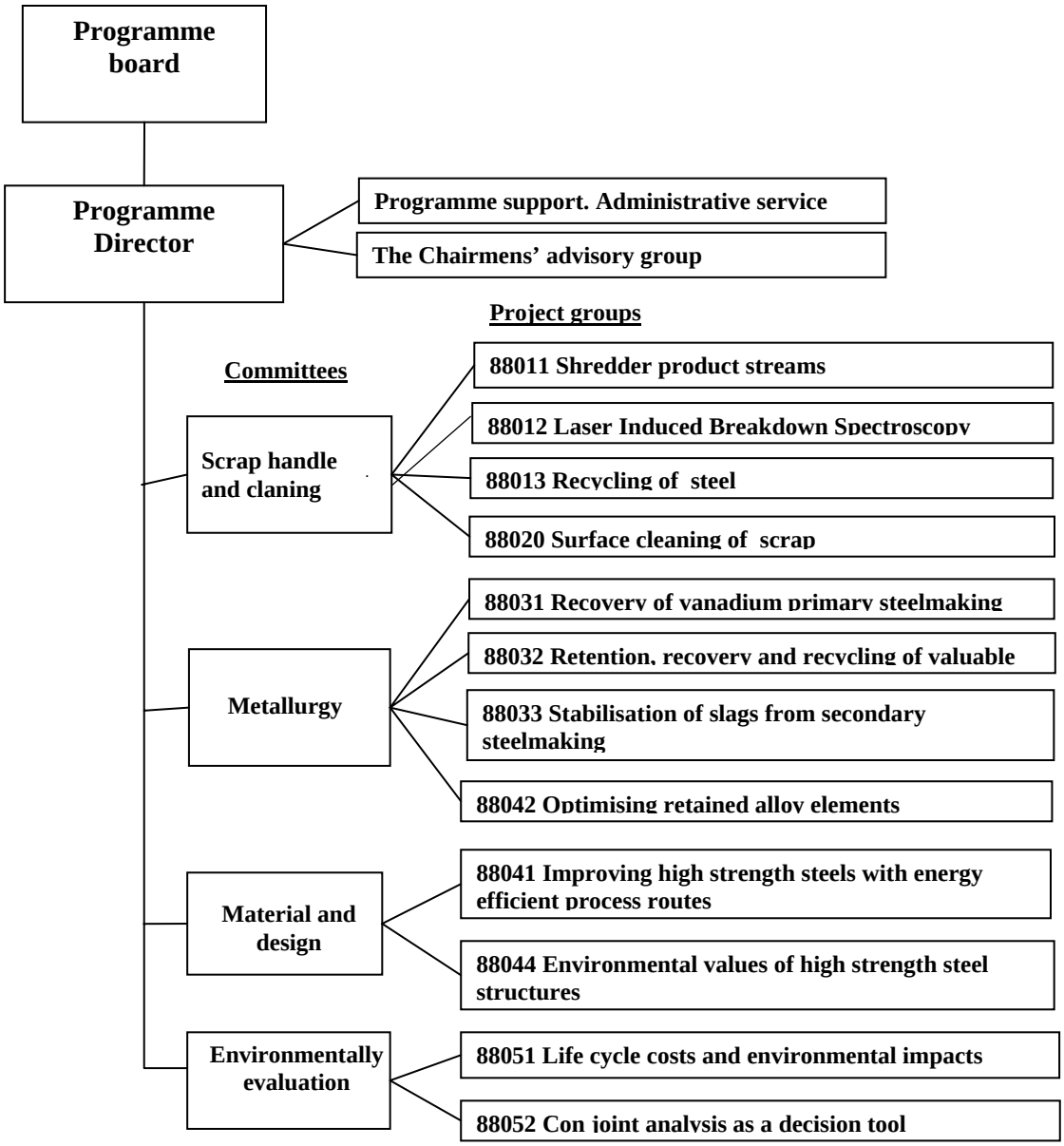

Figure 4: *Organisation chart of The Steel Eco-Cycle programme.*

The following companies and research bodies participate in the Steel Eco-Cycle Programme, together representing a huge national and international network serving the progress of the programme.

Industries

AGA AB
Bombardier Svenska AB
Electrolux AB
Erasteel Kloster AB
Fundia Armeringsstål AS
Höganäs AB
AB Järnbruksförnödenheter
Kuusakoski AB
LKAB
Merox AB
MultiServ AB
Outokumpu Oyj
Outokumpu Stainless AB
Outokumpu Stainless Oy
Ovako, Oy AB
Ovako-Smedjebacken AB
Rautaruukki Oyj
RHI Refractories Nord AB
AB Sandvik Materials Technology
AB Sandvik Tooling
SSAB Oxelösund AB
SSAB Svenskt Stål AB
SSAB Tunnplåt AB
Stena Gotthard AB
Stena Metall AB
Uddeholm Tooling AB
Volvo Car Corporation
Volvo Personvagnar AB

Universities, institutes and associations

Högskolan i Kalmar
IVL Svenska Miljöinstitutet AB
KIMAB, Korrosions- och Metallforskningsinstitutet AB
Kungliga Tekniska Högskolan
Luleå Tekniska Universitet
MEFOS
MinPro AB
Stålbyggnadsinstitutet
Svenska Gjuteriföreningen Service AB

Eurofer
Jernkontoret