THE STEEL ECO-CYCLE – A SUSTAINABLE MANUFACTURE AND USE OF STEEL

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ABSTRACT

The vision of the research programme "The Steel Eco-Cycle" is to close the loop in the manufacture and use of steel in the society. Results from the programme are anticipated to significantly contribute to saving of natural resources and energy in the manufacturing and use of steel. For example this will be accomplished by optimising the use of alloys to keep them in the steel products and at the same time produce slag which can be used instead of virgin construction materials. In Steel Eco-Cycle concept, slag design in the steelmaking processes has an extremely important role. Concerted efforts of the industrial and academic research are currently focused on a nation-wide effort to design slags that would have improved physical and chemical properties. Modified processes will save energy, minimize the loss of metal values like Cr, V or Mo to the slag, and produce slags for civil applications.

The project concept has been evaluated as unique in the world, with a strong support from Swedish strategic funds. The features of the Steel Eco-Cycle concept and the progress so far are being presented.

INTRODUCTION

The *Steel Eco-Cycle* [3] is an integrated research programme initiated and organised by the Swedish steel industry to meet future demands for eco-efficiency: from customers, the public, and authorities. The focus is on the conservation of natural resources and energy (eco-efficient manufacturing), safe use, and recyclability. The vision of the proposed research programme is: *closing the loop in the manufacture and use of steel in the society*. The proposed programme is the first large and coherent research effort directed towards an integrated analysis of environmental aspects in the steel industry in Sweden.

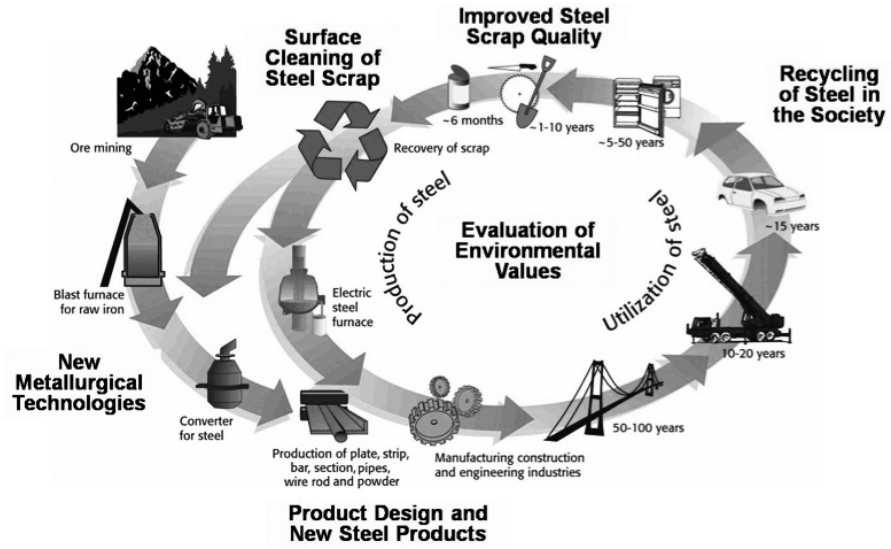

Figure 1: The steel eco-cycle

Political demands and environmental requirements stipulated by the European Union (EU) necessitate reinforced efforts and make the environmental challenges even tougher. The EU legislation is composed of both direct-acting regulations and directives that subsequently become incorporated into Swedish law. Policy communications also help to shape forthcoming legislation, e.g. the Integrated Product Policy (IPP) adopted by the Commission in 2003 [1], that calls for an overall use of Life Cycle Analysis (LCA), which is then expected to lead to a reduction in the negative environmental effects from all stages of any given industrial cycle or any given product. The *Steel Eco-Cycle* research programme has been created and designed to deal with the above challenges.

OECD (Organisation for Economic Development and Co-operation) has a programme on materials flows and resource productivity that supports the implementation of the OECD Council recommendation adopted in April 2004. The activities include annual workshops and a series of guidance documents [2].

The objectives of the *Steel Eco-Cycle* research programme are:

- To prepare the industry for new political demands and legislation with regard to the environment, which are presently in progress or being considered for the future
- To develop new methods for the assessment of environmental values in the early stages of the research and the development chain
- To operate process and product R&D projects with high environmental potential and high industrial value, embracing the entire steel eco-cycle

- To stimulate the exchange of knowledge and research efforts across the entire steel eco-cycle
- To increase the number of technicians from the industry and staff from research bodies who deal with environmental issues.

The ability to communicate the environmental performance of processes and products 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 and environmentally optimised processes, materials and products.

The support of the Swedish steel industry, together with the mining, scrap handling, and manufacturing industries, of the *Steel Eco-Cycle* ensures that the results from this research will be used and benefit the industry itself, with additional environmental and economic benefits for the society.

METHODOLOGY

The organisation of the *Steel Eco-Cycle* contains a total number of twelve projects and is co-ordinated to achieve cross learning and stimulate cross research over the entire steel eco-cycle.

The research programme is set towards the goal of conserving natural resources and energy. The fulfilment of this common goal requires the application of scientific knowledge from both basic science and the engineering disciplines. This is sometimes referred to as interdisciplinary research, but here we prefer to use the term multidisciplinary to stress the importance of the different individual components. Each project within the programme has its own specific goals, research designs, and methods. Many of these projects are also multidisciplinary in that they rely on theories and methods from several different fundamental disciplines to address the issues at hand.

Most of the projects, however, have their common base in the traditional science and technological disciplines, where variants of critical rationalism are the foundations of the research paradigm. Typical common research methods thus include designed experiments and hypothesis testing, or the evaluation of observation data against hypothesised models. These common approaches undoubtedly facilitate the understanding, interaction, and collaboration among the scientists and industries involved. All projects are based on fundamental or applied research at universities and research institutes in Sweden followed by testing in the participating industries.

The technical projects in the programme will make it possible for the industry to recover valuable metals, decrease or eliminate the use of landfills, and secure domestic raw materials. Much of the interest outside the mining, steel, scrap handling, and manufacturing industries will focus on results from the environmental evaluation studies, i.e. environmental performance.

One important outcome is the expected effect on recirculation and scrap balance. Steel is a material that can be recovered and recycled almost any number of times without loosing its valuable properties. This gives an important economical value to steel scrap. It is also synonymous with conserving natural and energy resources. The programme is expected to increase the availability of scrap of a defined quality.

The following projects are included in the programme:

Evaluation of Environmental Impacts

Environmental assessment of the technical projects and communication of results back to researchers during the duration of programme. Estimation of the cumulative environmental effects at the end of the programme. Development of a software tool for environmental evaluation of steel processes and products.

Attitude and Knowledge – A Basis for an Efficient Environmental Communication

An investigation on how attitudes control and affect the environmental work and company strategies through case studies of parts of the steel eco-cycle. Two case studies will be performed, on attitudes towards new materials and hazardous substances, respectively.

Improving High Strength Steels with Energy Efficient Processing Routes for Environmental Benefits

Optimisation of slab reheating temperature/time, processing and cooling parameters to improve mechanical properties of steels and for environmental benefits. Laboratory studies followed by verification with full-scale/pilot hot rolling processes.

High Strength Steel Structures for Reduced Environmental Impact

The tentative models for LCA and LCC will be further refined and extended. Real life case studies will be performed to get good examples and speed up the introduction of advanced high strength steel for weight reduction. Distribution of this knowledge to key groups as well as to small and medium size companies.

Recycling of Steel in the Society

Development of a refined version of the model, which can simultaneously analyze the material flow, recirculation, and losses of several elements.

On Line Classification of Steel Scrap Using Intelligent Evaluation from a CCD Spectro-Meter Equipped LIBS

Development of a low-cost prototype LIBS (Laser Induced Breakdown Spectroscopy) instrument, in order to make state-of-the art LIBS technology for scrap sorting available to a wide range of industries using scrap. The prototype will be tested in real-world applications.

Surface Cleaning of Steel Scrap

A pilot scale equipment of enough capacity is planned. Cleaned scrap will be produced and tested in full-scale production in an integrated steel plant.

Optimization of Unit Processes in Steel-Making Towards The Loss of Metal Values in Slags and Dust

Minimisation of metal losses (Mo, Cr, V, Nb and Mn) to slag and dust. Thermodynamics for Cr and V are investigated. Mo retention and Cr-loss are studied in different series by lab experiments and some industrial trials. Computer model for decarburisation and Cr loss is to be developed.

Development of a Novel Process Route for Recovery of Metal Values from Slags and Dust by Molten Salt Extraction

Extraction of metal from slag into a salt phase, and subsequent electrolysis of that phase, is investigated. Laboratory studies and synthesis into one process are carried out, before

upgrading to pilot and industrial implementation scale.

Leaching Mechanisms and Long Time Quality of Steelmaking Slag

The long-term quality of modified slags and how an increased Mn content in slag will influence leaching of metals are investigated. Theoretical studies are performed on distribution of Cr molten slag/solid phases, together with full-scale modification trials and sampling at an early stage.

Recovery of Vanadium in LD-Slag – VILD

Development of a cost efficient method for production of ferrovanadium based on Swedish LD-slag. Thermodynamic studies will continue. Further development of both reduction and oxidation steps, and verification with full-scale experiments.

RESULTS AND DISCUSSION

The *Steel Eco-Cycle* programme operates 10 technical development projects each whose potential environmental significance has been evaluated based on life cycle assessment (LCA) methodology. This study demonstrates considerable environmental gains when the programme is fulfilled and the results have been implemented in the industry. The evaluation shows that the programme provides a significant potential contribution to the conservation of natural resources and energy in the manufacturing and use of steel. The projects of the programme have the potential to provide technical solutions for reductions in CO_2 emissions and energy consumption exceeding the programme objectives, for the Swedish steel industry. There is also a potential to save material resources and mitigate other aspects that have a negative influence on the environment in addition to resource consumption and carbon dioxide emission.

The total potential process savings for the Steel Eco-Cycle programme are presented in Table 1. CO_2 emission and energy consumption are shown together with examples of other benefits, e.g. savings of raw materials such as alloying metals and avoided landfilling of metal containing slag and dust.

Table 1: The total potential process savings and other savings for the steel eco-cycle programme, including upstream and downstream processes

Elements		Goal	Total (including upstream processes)
CO_2	Ktonne/year	1 000	1 900
Energy	GWh/year	600	9 500
FeV (as pure V)	Tonne/year		3 700
Cr	Tonne/year		28 000
Ni	Tonne/year		2 000
Mo	Tonne/year		340
Mn	Tonne/year		50
Iron ore pellets	Tonne/year		630 000
CaO	Tonne/year		58 000
Crushed aggregates from rock	Tonne/year		280 000
Landfilling of slag and dust	Tonne/year		430 000
Waste management of ASR (Automobile Shredder Residue)	Tonne/year		170 000

The four projects concerning slags play an important part in the savings in Table 1. The decreases in energy consumption and emission of CO_2 are 25% and 50% respectively of the total savings. Slags with less metal content can be better used than today in the iron- and steelmaking processes and also externally. That means less use of raw materials and less landfilling.

CONCLUSIONS

The outcome of the Research Programme *The Steel Eco-Cycle* so far indicate that results of high industrial and scientific value and relevance have been achieved. Processes and procedures have been developed which can be brought forward towards realisation by the industry. The benefits with a better treatment of slags and dust can be found globally and not only in Sweden.

ACKNOWLEDGEMENTS

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