KEY FEATURES HOW TO TREAT ALUMINIUM IN LCAS, WITH SPECIAL REGARD TO RECYCLING ISSUES - A GUIDANCE DOCUMENT FOR LCA PRACTITIONERS

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The aluminium industry applies LCA as a technique to identify significant environmental aspects of its products in order to improve the environmental performance of these products during their whole life cycle.

Customers of the aluminium industry, e. g. the automotive or the building industry, when designing their products, chose between different materials including aluminium. The degree of market penetration of aluminium for a given application depends on economic, environmental and social criteria. LCA studies help to position aluminium in the environmental discussion.

Politicians use LCA studies as a basis for environmentally motivated decisions or regulations. Such consequences may affect the aluminium market significantly.

In the past, results of such studies varied to a high degree because of different methodological approaches. Now, the standards of the ISO 14040 series have set common methodological rules, which have to be applied to all LCA studies including those dealing with aluminium.

The European Aluminium Association (EAA) has published LCA data for different aluminium products. The aluminium industry is actively promoting the careful use of these data based on state-of-the-art methods.

The following key features illustrate the ISO rules and focus on the major crucial aspects of aluminium in LCA S, e. g. energy aspects, the high recycling rates and the high value of aluminium after recycling. These statements made should be considered when working out an LCA study dealing with aluminium products.

ZINC ECOPROFILE DATA: THE RESULTS OF A PAN-EUROPEAN STUDY

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The results of a pan-European ecoprofile study, commissioned by IZA/IZA-Europe, are presented. This project was intended to provide information on primary zinc production in Europe and the collaborative efforts of IZA and its member companies provided data on nearly 82% of total European SHG zinc and zinc alloy production.

Both electrometallurgical and pyrometallurgical zinc production processes were analysed. The scope of the study also included the production and transport of concentrates used by the primary zinc producers and covered the extraction of ores both in Europe and North America.

Primary zinc producers are also responsible for producing a large number of co-products and one of the most important techniques to be applied when studying such systems is co-product allocation of inputs and outputs. Metallurgical extraction systems are usually heavily constrained by the stoichiometry and thermodynamics of the extraction process. As a result of the analysis, ecoprofile data were also generated for several co-product streams such as sulphur dioxide/sulphuric acid, cadmium, mercury and lead. The benefits of this approach can be readily applied to studies of all metallurgical extraction processes and part of this paper is concerned with the more general principles for establishing criteria for co-product allocation in metals systems.

EUROPEAN LCI STUDY ON STAINLESS STEEL FLAT PRODUCTS

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A Life Cycle Inventory study on certain stainless steel flat products has been conducted in Europe. It involved the majority of the main stainless steel producers in the EU, and was conducted in two phases: first, a gate-to-gate study on the defined products and second, incorporation of the results of studies that had been carried out in parallel on the alloying elements (chromium, nickel and molybdenum). Hence, a cradle-to-gate LCI was developed for a multi-component metallic alloy.

This was a complex exercise and very costly in terms of both time and money. The complexities included how to accommodate different sources of the raw materials, some of which may not have been included in the LCI for the particular alloying element. There are also questions relating to scrap. A high proportion of the feedstock for stainless steel production is scrap: is it possible/necessary to factor in practice at the time of first production, bearing in mind the longevity of many stainless steels products; or the number of recycling cycles and/or efficiency of recycling? And, if the results are to be used by a third party, will the assumptions within our database on, for example, materials sources and recycling match the presumptions of the data user?

However, within the caveats of our assumptions, database analysis enables evaluation of the different process flows from "cradle" (raw materials, energy inputs) to "gate" (products and outputs to air or water). One use of this analysis is to identify different targets, in terms of industrial process and waste management, that it may be possible to modify to improve environmental performance.

Going beyond the gate takes us into a whole new set of complexities: stainless steel is an extremely widely used product with an immense range of industrial, architectural, domestic and medical applications. Some of these use large quantities, others use much less; and some products have lives of at least decades while others may be short-lived. Taken together with the question of recycling statistics and their reliability, “beyond the gate” is a problem yet to be tackled.

LIFE CYCLE INVENTORY MODELLING IN THE SWISS NATIONAL LCI DATABASE ECOINVENT 2000

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In late 2000 the project ECOINVENT 2000 has officially been launched. Several Swiss federal agencies and nine institutes of the ETH domain agreed on a joint effort to harmonise and update life cycle inventory (LCI) data for its use in life cycle assessment (LCA).

For that purpose a central database will be developed building on past experiences with a large network-based LCI database developed at ETH Zürich. The database will comprise LCI data from the energy, transport, building materials, metals, chemicals, paper and pulp, waste treatment and agricultural sector. The content of the database will be made publicly available via the web.

Two technical aspects are highlighted in this presentation, namely the data (exchange) format and the data compilation quality guidelines. The aspects are illustrated with examples from the metal industry. The data (exchange) format allows for a extensive description of unit processes, including technical, geographical, temporal and administrative details. Life cycle inventory data can be entered into the database on a unit process level which leads to the highest degree of transparency. Confidential unit process data will be managed by only showing their cumulative results to the public. XML-technology is applied for the data exchange between the institutes and between them and the central database. This allows for a flexible solution and gives the opportunity to consider the particularities of different LCA software products on the market.

Quality guidelines have been developed in the project group in order to facilitate and harmonise the data acquisition process and to ensure a consistent and homogeneous life cycle inventory data compilation. Common rules are defined for issues such as electricity mix applied, pollutants reporting, land use, allocation procedures, transport distances and the like.

COMPARATIVE ANALYSIS OF SEVERAL NON-FERROUS METALS LCA

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Driven by increasing regulatory and market-based pressures, the non-ferrous metals industry has over the past few years undertaken a number of large Life Cycle Assessments (LCA) of their products. Carried out mostly by industry organizations independently of each other, these LCA projects have been varied in scope and objectives. For example, some included only the Life Cycle Inventory (LCI) stage of the LCA while others extended their approach into Life Cycle Impact Assessment (LCIA). Furthermore, some studies were focused on the cradle-to-gate profile of the raw material (as supplied to other industrial customers) while others included a full life cycle of a final application (e.g., starting and lighting battery).

However, a constant theme of these studies has been the challenges associated with the LCI methodology and modeling of the production of these metals. These challenges have occurred for the most part because of the intricate nature of the metal industry itself and the different methodological issues to overcome when tackling such a study (e.g., treatment of coproducts, recycling loops, etc.). In addition, some of the methodologies traditionally encountered in the LCA literature are not necessarily applicable to the metal industry as they have been largely derived from other studies sponsored by other industry sectors (especially the plastics industry).

This talk will present some of the key methodological differences and similarities of several large metal LCA studies that have been performed. It will also address the practical challenges that users of these studies are continuously facing, such as dealing with studies performed under differing goals and objectives; data robustness and comparability; and differing data categories. The issue of recycling will also be addressed.

Proposal for new Allocation procedures for Steel recycling.

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ABSTRACT

The Steel industry of Canada continued the efforts over the past five years to improve the performance in the reduction of energy, emissions to air and water, and the re-use of recyclable materials. This industry possesses a well-designed and implemented Environmental Management System and it has best-in-class operating practices. It would naturally like to be seen as providing an environmental service when recycling scrap and waste materials and it should obtain an energy or environmental credit for recycling. The home scrap and the prompt scrap, used in BOF, DRI/EAF and EAF mills “embodies” some of the energy originally used to produce the steel returned to the mills. The obsolete scrap should be declared free of any energy, or environmental charges other than those incurred in direct processing and transportation.

The ISO 14041:1998(E), s. 6, “Allocation of flows and releases” presents Life cycle inventory analysis, allocation principles, and procedures for reuse and recycling of steel. Many other authors use this methodology. We found that this methodology is very cumbersome and requires arbitrary decisions that might not always be consistent with normal engineering or scientific logic.

We present an alternative method for determination of allocation factors that requires setting up logically consistent philosophy of energy and pollutant embodiment to scrap and products. A computer model containing this philosophy lets the modeled system cycle until input and output of material flow, energy usage, and/or pollutants weight is balanced. The allocation parameters are numerical outputs from this model that do not require or allow any arbitrary inputs or adjustments.

This paper examines the above issues and recommends an approach for future evaluations of the Canadian, USA or the world Steel Industry. Its principal goal is to show how to attribute energy and the environmental impacts to the various categories of recycled steel.

LIFE CYCLE ASSESSMENT OF NICKEL PRODUCTS

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The experience of this metal's LCA on its primary products is presented. The motivation, study goals and intended uses are briefly reviewed. More attention is given to the study scope, boundary and methodology. The approach to co-product allocation is described, including the provision made for SO_2 when SO_2 production is optimized for fertilizer production (ammonium sulphate). The impact categories are touched upon, including the reservations on the current approach to Natural Resource Depletion. The greatest attention is given to the difficulties and challenges faced by non-practioners when dealing with data (collection, quality assurance, manipulation), production process variation (common in the nickel industry), and different ore types (oxidic versus sulphidic). The paper ends with a brief description of how the nickel industry plans to continue its work with LCA.

LIFE CYCLE INVENTORY ANALYSIS OF CO_2 EMISSION FROM COPPER PRODUCTS MANUFACTURING SYSTEM IN JAPAN

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CO_2 emissions from the copper products manufacturing system were quantitatively evaluated using Life Cycle Assessment (LCA) technique. Copper and brass products in several shapes, copper cable and sulfuric acid were produced in this system. In this study, inventories such as the fuel consumption of the smelting and the processing stage were based on public statistical data. The following observations were made based on LCI analysis:

(1) CO_2 emissions from the electrolytic copper and sulfuric acid in the system are about 1.0kg and 0.4kg/kg-product, respectively. The CO_2 emissions attributable to the transportation of copper concentrate correspond to 20% of all emissions. This emission is higher than that of zinc, because the metal content in the concentrate is lower than zinc.

(2) CO_2 emissions from the copper products system are in the range from 1.4kg to 2.24kg/kg-product, respecting the materials consumption and the energy consumption to process the products. The CO_2 emission attributable to the processing corresponds to 50% of all emissions.

(3) The reduction effects of CO_2 emissions from the system are larger with the recycling of copper alloy scrap to the brass processing than that to the converter, if the amount of scrap consumption is fixed. However, the recycling leads to the decrease of sulfuric acid.

The recycling of scrap should be evaluated not only from the reduction of CO_2 emissions but also in terms of land use and saving of unrenewable mineral resources and so on.

AVOIDING CO-PRODUCT ALLOCATION IN THE METALS SECTOR

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Compared to traditional co-product allocation, system expansion according to ISO 14041 provides a more realistic modelling of the actual consequences of product related management decisions. Through a number of examples, including recycling of steel and aluminium, it is demonstrated how co-product allocation can be avoided in practice. The example of platinum-group metals is used to illustrate how system expansion can sometimes be used as a justification for economic allocation.

CERTIFIED LIFE CYCLE IMPACT PROFILE OF NORTH AMERICAN STEEL PRODUCTION LCIA STUDY CONDUCTED BY SCIENTIFIC CERTIFICATION SYSTEMS OAKLAND, CALIFORNIA

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The North American steel industry contracted with Scientific Certification Systems (SCS), a recognized neutral third-party certifier of industrial environmental claims, to evaluate the science of life-cycle assessment (LCA), and to examine its potential applications in assessing the environmental performance of steel production. Drivers for this work included customer demand, competitive considerations, and the industry's internal need to assess improvements.

While past environmental assessments have portrayed the steel industry as energy intensive and highly polluting (DOE 1996), the steel industry believed that a more robust, comprehensive scientific methodology such as advanced LCA might more accurately reflect its performance and achievements.

The study, now completed and peer reviewed, demonstrates that advanced LCA -- specifically, life-cycle impact assessment (LCIA) conducted in accordance with international standards -- does satisfy the need for a rigorous and comprehensive scientific assessment method capable of presenting an accurate environmental impact profile of steel production. Moreover, the study findings show the significant environmental progress that has made by the North American Steel Industry in its steel production operations.

It is anticipated that the results of this study will be of assistance to the steel industry for market-based claims, to support public policy positions, and to help guide regulatory reforms.

Methodology

During the course of SCS's research, it became evident that historic LCA techniques focused on life cycle inventory (LCI) alone could not produce environmentally relevant results, and as such, could not supply information suitable for environmental decision making to the industry, its customers or stakeholders.

To overcome the shortcomings of this traditional approach, SCS utilized advanced LCIA techniques for this study. By integrating environmental data from other techniques such as traditional environmental impact assessment (EIA) and risk assessment (RA) into the overall LCA calculation framework, the methodology converts raw LCI data into environmentally relevant impact indicators. The methodology addresses all relevant environmental issues of resource depletion and emission and waste loadings, providing a quantitative basis by which to establish an overall LCIA impact profile for products and materials.

Goal of the Study

The primary goal of the study was to conduct a site-specific LCIA of steel production, including all significant upstream processes -- in particular, coal mining and iron ore mining.The results of the study were then to be used to develop a Certified Life-Cycle Impact Profile for steel production, and a Certified LCIA profile for steel framing for residential construction to be used as the basis of comparison with wood framing.

Key Findings

- ***Steel Resource Depletion***

Under LCIA, the depletion of resources is assessed rather than merely analyzing the amount of resources used. Depletion calculations take into account the rate of use, the size of reserve bases, recycling rates, and natural accretion, providing a more accurate measure of the impacts an industrial system on future availability of the resource. This study represents the first formal integration of the available steel currently in use (i.e., standing stock) as part of the overall reserve base of overall iron resources. The integration of the standing stock reserve base with ongoing recycling rates allowed for the accurate calculation of iron resource depletion rates. The study confirms that the depletion of iron resources is approaching zero, indicative of a "sustainable" resource. As such, this is the first study to put recyclable resources such as steel on a comparable footing with renewable resources such as wood. The result should help move the debate about resources from renewability versus non-renewability to the more fundamental issue of sustainability.

- ***Energy Resource Depletion and Embodied Energy of BOF Steel Production***

The depletion of energy resources was assessed rather than merely analyzing the amount of energy resources used. In this study, the most significant depletion of energy resources was found to come from the use of natural gas for electricity supplied from the grid, and not from the usage of coal. This study, furthermore, separated out energy use as heat from energy resources used to reduce ore into iron. This separation allowed for the calculation of the total residual embodied energy inherently bound into reduced iron. These results, in turn, can be used to more equitably allocate overall energy resources depleted between BOF and EAF production.

- ***Physical Disruption***

Direct impacts to terrestrial and aquatic habitats from physical operations are accounted for under the impact indicator, Physical Disruption. Most of the physical disruption from steel production is associated with mining activities. Significant differences were noted between the physical disruption associated with abandoned mines as compared to reclaimed mines, demonstrating the value of reclamation. This physical disruption was quantifiable. When put into the context of the amount of steel produced annually (2.3 million metric tons), the area of physical disruption attributable to steel production was less than one percent of the "best case" physical disruption from sustainably managed forestry operations producing an equivalent number of wood framing materials.

- ***Greenhouse Gas Loadings***

The most significant greenhouse gas loadings were attributed to the CO_2 emissions from steel making and coking, and surprisingly, to methane released during mining. If current efforts at recovering the methane liberated from the mining operations are successful, the LCIA profile would show a significant reduction in total greenhouse gas loadings.

- ***Acidification Emission Loadings***

Most of the acidification loadings documented in this study were associated with SO_x and NO_x emissions from the combustion of coal for both coking and electricity unit operations. The calculations showed that only a small fraction of the emissions result in measurable effects on the environment. These calculations demonstrate how misleading it can be to report "worst case" LCI data to customers, government and stakeholders.

- ***Criteria and Hazardous Air Pollutant Emission Loadings***

Air pollution control is an area in which the steel industry is heavily regulated and which receives the most significant attention from public interest groups. Over the years, the industry has made significant process changes to reduce air pollution, such as eliminating the sintering process, resulting in significant reduction in environmental loadings from emissions.

The criteria and hazardous air pollutant indicator results were surprisingly low for all steel making processes. These indicator results reflect the extensive nature of both equipment, air pollution controls and administrative controls to ensure that operations stay below threshold levels for PM-10 and other air contaminants. In addition, risk assessment of emissions of benzene soluble organic compounds (BSO's) were also addressed in the study and found to be below deminimus. These indicator results have significant regulatory implications for the steel industry.

- ***Water Emission Loadings***

Similarly, the blast furnaces and coke batteries studied demonstrated sophisticated wastewater treatment, which after extensive assessment was show to have virtually eliminated any toxic aquatic emission loadings from their wastewater effluent.

- ***Waste Management***

The study reconfirmed that much of the waste generated from individual unit processes is used as feedstock for other unit processes or is recycled for use in roadbeds and other beneficial uses.

Metals, LCA, and the ISO 14041 Allocation Procedure for Recycling

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Allocation procedures in LCA have long been a contentious issue. The International Standard ISO 14041 defines allocation procedures for recycling, which are particularly relevant for the metals industry.

If, for example, a metal component is studied, the functional unit might be described in terms of the service provided by the component (e.g. housing the equipment for 50 years). The LCA system boundary would obviously include metal production and processing, component manufacture and delivery, component use and maintenance and end-of-life. The recycling issue arises at end-of-life-where the component is presumably collected and treated. At this point the metal's former life ends and a new life begins. The metal output of the recycling activity is not included in the original component's product system.

Recycling raises interesting questions. Should recycling be treated as a waste management activity or as a material production activity? How should the environmental loading associated with recycling be assigned between the new freshly recycled material versus the previous end-of-life metal? Where does one product end, and the next begin?

The International Standard ISO 14041 on LCA has addressed these questions, in fact, with special attention given to metals. In cases where the recycled material is downgraded in quality, it is treated like any other coproduct from the system. But where the "material is recycled without changes to inherent properties" [ISO 14041 clause 6.5.4], it is treated as if it replaces virgin materials, *a closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems,* ***where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.***

In other words, this clause allows one to allocate the share of virgin and recycled metal used in a product on the basis of the recycling of the metal in the product at the end-of-life. Essentially, LCA therefore promotes the stewardship of metals.

LCA is the dominant analytical tool for product-focused environmental assessments. As illustrated above, it is important in an LCA study to determine the appropriate boundaries of the system being evaluated. These boundaries affect the functional unit and the ability to measure a range of environmental impacts and benefits that may otherwise be missed, for example those that may be realized over the longer term. This is of particular interest to the metals industry, since many of the valuable properties of metals (such as recyclability, durability, strength, etc.) are often overlooked in environmental assessments. The allocation procedure in LCA helps with this matter. With LCA - and other tools - the environmental value (as well as the environmental burdens) of products and materials will be progressively recognized.

Life Cycle Inventories for Minerals Processing in South Africa and Australia and their Use in Decision Making for Technology Choice

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This paper presents " base line" life cycle inventories for minerals processing in South Africa and Australia, supported by detailed process models of technologies in place within the industry. Particular attention is given to the identification of the requisite level of process information needed to support inventory development, and how this is informed by the context in which the information is to be used. We argue that there exists significant potential to streamline data collection.

The use of these inventories to support decision making around technology choice is highlighted. Case studies in coal mining and copper processing are used to demonstrate this approach.

Lessons gained from this exercise suggest how it is possible to develop inventories for minerals processing activities in other regions of the world.

Some consideration is given to the use of this information set in developing impact assessment profiles. Problems in this regard are highlighted. The trade-offs between global and regional impacts are identified as a consequence of regional development of minerals resources. Some comment on the implications of increasing the recycling potential of primary metal products is offered.

CONSISTENCY AND COMPARABILITY ACROSS MATERIAL GROUPS – THE US LCI DATABASE PROJECT EXPERIENCE

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This keynote presentation will be set against a backdrop of rapid and fundamental change whereby environmental trends and issues are becoming progressively more dominant, affecting business decisions from production through marketing. The role of LCA will be positioned against this backdrop, making the point that the LCI is the critical footing on which all subsequent LCA steps rest. A distinction will be made between generic and supplier-specific LCI databases, with a brief discussion of the importance of each and their interrelationship. This is an especially important distinction for any subsequent workshop discussions about methodological issues, as is the distinction between attributional and consequential LCAs.

The US LCI database project, especially the first phase protocol development process, and the experiences of the Athena Institute and other organizations, will provide illustrations of some of the practical problems facing practitioners, and serve as a basis for highlighting selected methodological issues and problems. Another important distinction will be made between LCA practitioners serving the needs of individual clients, with narrowly defined goals, and those serving a broader 'public' demand for data and for various kinds of decision support tools. In the latter situation, consistency and comparability across material groups are critical criteria that most often prevent the use of available LCI databases.

Central to the completed first phase of the US LCI Database Project, which focused on the development of an appropriate research protocol, have been debates about the real meaning of transparency and about such issues as co-product allocation and recycling and reuse, particularly of metals. These are all subjects of lively debate where the ISO 14041 standards, like the US constitution, become a matter for expert opinion about real meanings and intents. The debates are interesting, even entertaining, but the reason for the debate can easily be overshadowed, with academically interesting possibilities taking precedence over practicality. The challenge for the Theme 1 workshop participants is to stay focused on scientifically sound approaches that are also feasible.

Functionality and Allocation in a Multi-product Metals Refinery

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Metals are frequently won from complex ore deposits. Methods employed in the compilation of life cycle inventories thus need to be able to allocate burdens fairly through the main stages of metal production, viz. mining, concentration, and refining. Whilst unit operations in mining, and largely also in concentration, serve all metal values in the ore equally, refineries may employ special unit operations for specific metals. They may also have the flexibility to process concentrates from different sources and of very different compositions.

Defining a functional unit, and allocating burdens within the refining step of the metals value chain thus requires special attention. This paper presents observations from a case study on a base metals refinery producing Nickel, Copper and Cobalt, but also a PGM (Platinum Group Metals) concentrate for further processing in another refinery.

It has been documented that the definition of functionality becomes complex when studying the process life cycle of the refining operation. Whilst the main function of the refinery appears to be the processing of the feedstock to provide the PGM concentrate, significant earnings are also derived from the base metals. Further, toll refining activities may be engaged in, leading to a strongly altered environmental profile against a poorly understood functionality baseline. The provision of earnings to the operator may be regarded as an appropriate functionality, but this is a difficult concept to operationalise as the prices of the different co-products fluctuate significantly.

On the other hand, when the interest is to provide module data for cradle-to-market life cycles of unique metals, overall functionality of the refinery is of lesser importance, with the interest being on the provision of a set of standard flows relative to a reference flow. Nevertheless, to arrive at such a result, an assumption has to be made as to the "normal composition of the package of metal products" from the refinery, and an allocation method has to be selected. In the case study, it is shown that the assumption of such a standard package of metal products is not always justified. Moreover, even when such a standard package is produced, the relative magnitude of burdens between products may not be fixed. Here, this was found to be a function of the utilisation of processing capacity (or turndown). These observations suggest the need for more flexible interpretations of functionality and allocation in co-product systems, and provide some guidance for designers of minerals technologies in terms of choices of design variables.

METALLIC RAW MATERIAL FLOWS – INVENTORY ANALYSIS

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Metallic raw material flows interfere with a large number of sustainability issues. To identify challenges for the redesign of existing supply chains, a scientific instrument has been developed at the University of Technology, Aachen in cooperation with the Forschungszentrum Jülich to provide information on complex metal flow systems. This integrated resource management system consists of a set of tools which are designed to determine existing potentials and to estimate resulting ecological, economical and social effects of various actions.

Technical innovation represents one key challenge to reduce emissions and to increase resource efficiency. Therefore, a technology-orientated process chain model has been developed along the material flow of aluminium from mining, smelting, to recycling and disposal. Within this inventory each production level is represented by a variation of technology-specific and location independent modules. The technical status is classified into different technological categories. These are old technologies (OT), present technologies (PT), the newest available technologies (NT) already being in use, and technical options for future use (FT).

Beside the description of the present situation, scenarios are used to show possible future developments as well as their effects on material and energy flows, plant locations and resource productivity by choosing different technological developments.

Another key topic regarding metals and life cycle principles is the influence of recycling mechanisms on the material flow considered. Even if metals are fully recyclable according to their atomic structure, different alloy compositions and impurities can restrict the re-usability. Therefore, a product specific distinction between various alloy qualities is used to model the differences of their supply systems. In the sense of life cycle analyses this enhancement of the inventory enables the identification of specific potentials and the simulation of optimised recycling systems.

Parallel to the development and interpretation of scenarios for aluminium the above mentioned tools are extended and enhanced for the copper material flow.