STAINLESS STEEL IN A SUSTAINABLE SOCIETY

- what we know and what we need to investigate

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ECOCYCLE MODEL FOR STAINLESS STEEL

Scrutiny of the Ecocycle Commission's report (1997:14) entitled "A strategy for materials and goods adapted to the ecocycle" ("Strategi för kretsloppsanpassade material och varor"), revealed that stainless steel was treated as the sum of the metals chromium and nickel rather than as a unique construction material that offers strength comparable to that of iron.

Chromium's (18%) corrosion resistance in atmospheric environments and at high temperatures is attributable to a chromium oxide film, a mere 10 atoms in thickness, that forms spontaneously on the surface of the steel. This film protects the surface against further attack and the corrosion is gradually reduced. Aluminium and titanium benefit from the same self-healing mechanism in the form of a stable oxide film, whilst the corrosion products for iron and zinc provide protection that varies according to the environment and often results in linear metal losses. Nickel (8-20%) transforms the ferritic and brittle microstructure of iron to a tough and ductile austenitic structure.

A lower nickel content results in a hybrid structure (duplex) which combines the best properties of ferrite and austenite with high strength. Molybdenum (2-6%) enhances the resistance to aggressive acids and chloride solutions.

At the request of the Federation of Swedish Industries (Industriförbundet), a number of projects were launched to establish the facts about the metals used in our society. The report "Chromium, nickel and molybdenum in society and the environment" has been published.

To be able to give an overview of the quantitative environmental aspects in relation to economical considerations, we have developed an ecocycle model for stainless steel in Sweden (Encl. 1)
This illustrates, among other things, the following:

- that the production of stainless steel in Sweden has been developed from a traditional ironmaking society that involved close co-operation with downstream companies in the engineering sector and end-users in process industry. Stainless steel volumes world-wide have grown at a rate of 6% per year over the past 40 years. Today, stainless steel accounts for 2% of overall steel volumes and 10% of value, and in Sweden for 30% of the value
- that production is based on the recycling of steel scrap complemented by imported volumes and value-adding CrNiMo additions, in a mix that is determined by current market prices.
- that CrNiMo emission from the stainless steel ecocycle are small in relation to other technical ecocycles and to the natural ecocycle.
- that CrNiMo emissions from the "consumption" of stainless steel are lower than from its production

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However, the effects of the continuing technological developments towards higher productivity (fewer and larger manufacturing units) and greater environmental awareness (higher recycling, more stringent demands with regard to emissions and more efficient purification plants) are not evident.

Example from production in Avesta, Sweden:

	per year					per kton slabs, year				
Emissions to air	1970	1980	1987	1990	1997	1970	1980	1987	1990	1997
Dust ton	4800	570	266	127	18	40	5	1,5	0,7	0,05
S as SO_2 ton			230	47	26			1,3	0,27	0,08
NO_x as NO_2 ton			270	256	333			1,5	1,5	1,0
Slabs kton	117	109	179	171	346					
Hot/Cold rolled kton	44/20	34/44		42/50	601 +95/58					
Process equiv. kton	55	65		86	279	per kton process equiv., year				
Energy cons. TJ	1970	1930		1350	3120	36	30		16	11
Employees Manyears	3000				1200	55				4

- 1 Process equivalent 1997 = 0.24 casting, 0.21 hot rolling, 0.17 annealing, 0.38 cold rolling/annealing = 11 GJ/tonne

During the study, a number of basic facts became apparent:

- Chromium emissions from the production of stainless steel exceed emissions from the use of stainless steel. It was earlier claimed that emissions arising from use in Sweden had exceeded emissions from production.
- The accumulated volume of stainless steel in the Swedish technosphere is approximately 800,000 tonnes. This is approximately 10x lower than the figure derived from the trading statistics for chromium and nickel.
- Average emissions for all environments in which stainless steels are used total approximately 100 mg Cr/m^2, year. This is approximately 7x lower than estimates based on metal emission factors.
- Normal emissions for 18-8 steel in an outdoor environment is approximately 1 mg Cr/m^2, year.
  This is approximately 3000x lower than the corrosion for zinc and 1300x lower than for copper under the same conditions.
- Class 0 corrosion resistance in accelerated testing in chemical environments has a limit value of 140,000 mg Cr/m^2, year and the lowest corrosion category C1 for atmospheric corrosion according to ISO 9223 has the value 10,000 mg carbon steel/m^2, year. This means that the normal testing methods used when choosing between different alloys are too crude to be able to assess environment-related metal emissions.

DATA ON THE ENVIRONMENTAL IMPACT ARISING FROM THE PRODUCTION OF STAINLESS STEEL

AvestaPolarit is a member of CPM ("Centrum för Produktrelaterad Miljöanalys") and has previously submitted data from our Swedish production plants to the "Environmental Priority System" (EPS), used as an aid by design engineers. Within the framework of our European trade association EUROFER we participate in ECO-BILAN's compilation of data on stainless steel. This information was submitted earlier and has now been compiled, but not evaluated.

Of considerable importance for the size of the ELU values (Environmental Load Unit) for different stainless steel products is the sub-item for: Constituent metallic raw materials – Recycled scrap = Environmental load of metallic raw materials.

If the estimated degree of recycling is 98.5-97-94% this ELU post is changed according to the proportions 1-2-4.

In connection with Nordic Environmental labelling (Swan mark) of stainless steel water tubing, the question of recycling has been debated. Stainless steel has a long use life (30 years) and an increasing market demand (+5% per year). This means that only 20-25% of the scrap required to satisfy the stainless steel needs of today is available on the scrap market. The "recycling index" for stainless steel is thus low compared to the figures 80-90% for consumer products like newspaper and beer-cans.

Remaining 75-80% has to be covered by carbon steel scrap and virgin CrNiMo. Since the CrNiMo content of stainless steel is approx. 25%, the global need for virgin CrNiMo metal is ca 20% of today's used tonnage. (Figure 1)

BENEFICIAL ASPECTS OF STAINLESS STEEL

Together with IVL "The Institute for Air and Water Research" a semi-joint project has been launched - "Products that make efficient use of resources – the benefits of stainless steel" – the purpose of which is to quantify the benefits, relate them to the environment load disadvantages and to compare these values with alternative materials. Typical examples chosen are:

- Productivity/standard increases	Breweries, Pulp digesters
- Energy savings	Heat exchangers
- Reduction of emissions	Flue gas cleaning in oil-driven power stations and refuse incineration.

HEALTH ASPECTS

Managers at each of the manufacturing sites follow local working environment regulations. On going activities within the EU are being monitored by colleagues in Sheffield, and in 1996, we took part in the conference "Stainless steel and allergies". The important concept of "bio-availability" is being studied as part of an ongoing project at the Royal Institute of Technology (KTH) regarding the outflow of different metals from sheets exposed to an outdoor environment. The toxicity of metal ions on algae is being studied, as well as the chemical specification. It is proposed to continue the project within the government sponsored program "Sustainable Use of Metals".
A new study of standard test methods for nickel dissolved from alloys in contact with sweat and body fluids is under discussion.

ENVIRONMENTAL MANAGEMENT, CERTIFICATION AND MARKING

The Group's environmental policy of 1995 defines the responsibility of each unit to state environmental objectives and action plans. Annual environmental reports are drafted for operations requiring permits. A brochure distributed to all households in Avesta is attached as an example of local environmental activities. Work with environmental management systems in accordance with ISO 14000 has begun, as have studies regarding the integration of our quality management systems in accordance with ISO 9000.

A "Safety data sheet for stainless steel" has been drafted, according to the EU directive (Inf 9605)
We are looking into the possibility of making our own type II declaration in accordance with ISO 14021.2
We are continually responding to enquiries from the building sector in accordance with their requirements for trade descriptions.

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THE ECOCYCLE IN SWEDEN FOR STAINLESS STEEL

covers (Figure 3):

STEEL PRODUCTION During the 1990's annual production volumes have been 470 kton (1000 tonnes) of sheet/plate, strip, bar, wire and tube from some 600 kton of melting shop production. Sweden exports 420 kton and imports 60 kton. Domestic "consumption" of 110 kton goes to...

FABRICATION at about 500 workshops to manufacture finished products, i.e. equipment for processing water, food and pulp, for flue gas cleaning and sewage, as well as products such as architectural cladding, car exhaust systems, kitchen sinks etc. Most fabricated steel, around 65 kton, is exported, but we also import 20 kton. Scrap accounts for 10 kton, and finished products corresponding to 55 kton go to...

USE in both industrial (70%) and domestic applications (30%). Since discarded equipment account for 20 kton of stainless steel scrap, the yearly increase is 35 kton. Totally some 800 kton of stainless steel is used in Sweden today.

RECYCLING NEW RAW MATERIAL Scrap arising from fabrication and use is returned (~97%) to the three melting shops for re-melting. The melting shops also recover recycled metal from dust and other by-products. A total of 50 kton/year is recovered. The raw materials used in stainless steel production are mainly different grades of scrap (ore is not used). We need to import 290 kton of scrap (unalloyed, stainless, nickel alloys) The Cr/Ni/Mo content is compensated with 150 kton of raw materials with 60% alloy content.

EMISSIONS Cr/Ni/Mo ore is not mined in Sweden. From imported ore some 100 kton of ferro-chromium is produced as alloying material. The emission of Cr is 5 ton per year. Stainless steel is produced at 6 locations in accordance with the limits granted by local authorities. Deposition of slag/slime includes 8 kton Cr/Ni/Mo per year. The emissions released into air/water are estimated at 15 ton Cr/Ni/Mo per year, compared with 300 tonnes 20 years ago. The use of stainless steel equipment in industrial processes leads to lower levels of corrosion, estimated at 3 tonnes Cr/Ni/Mo per year. However, these diffuse emissions to treated organic and mineral substances correspond to merely tenths of a percent of their natural Cr/Ni/Mo contents

Figure 1

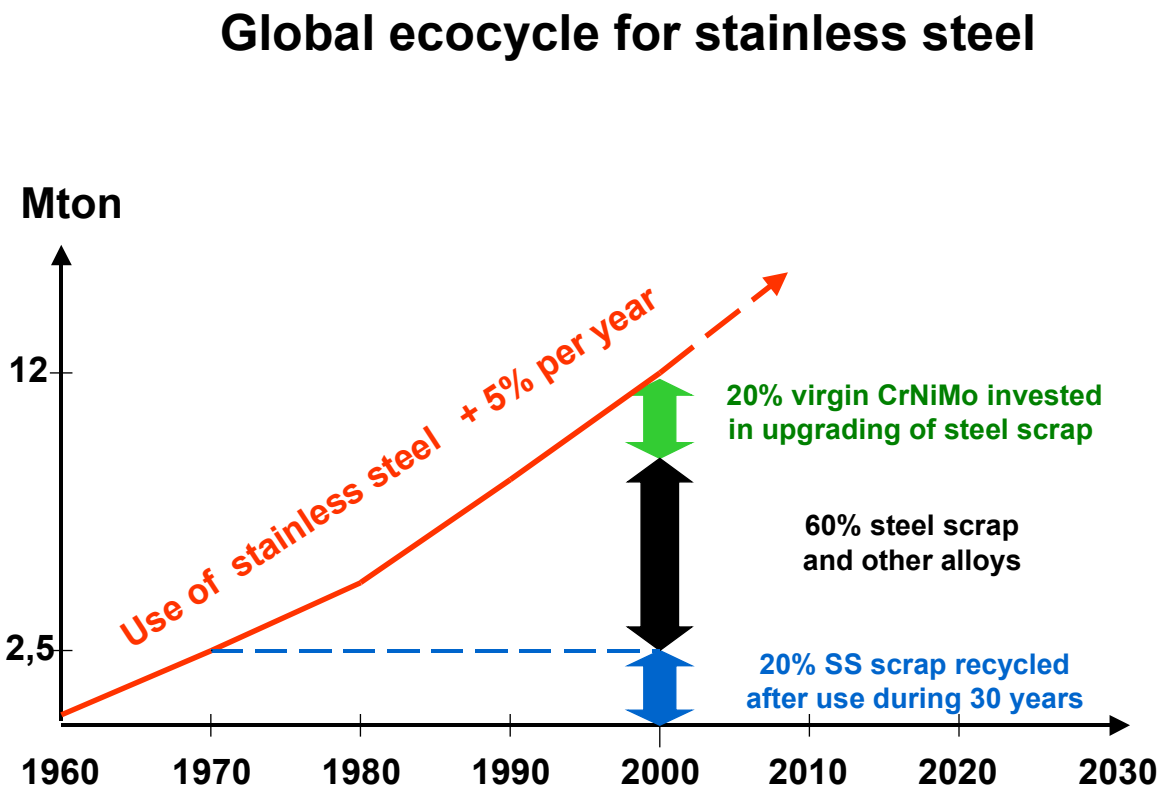


Figure 2

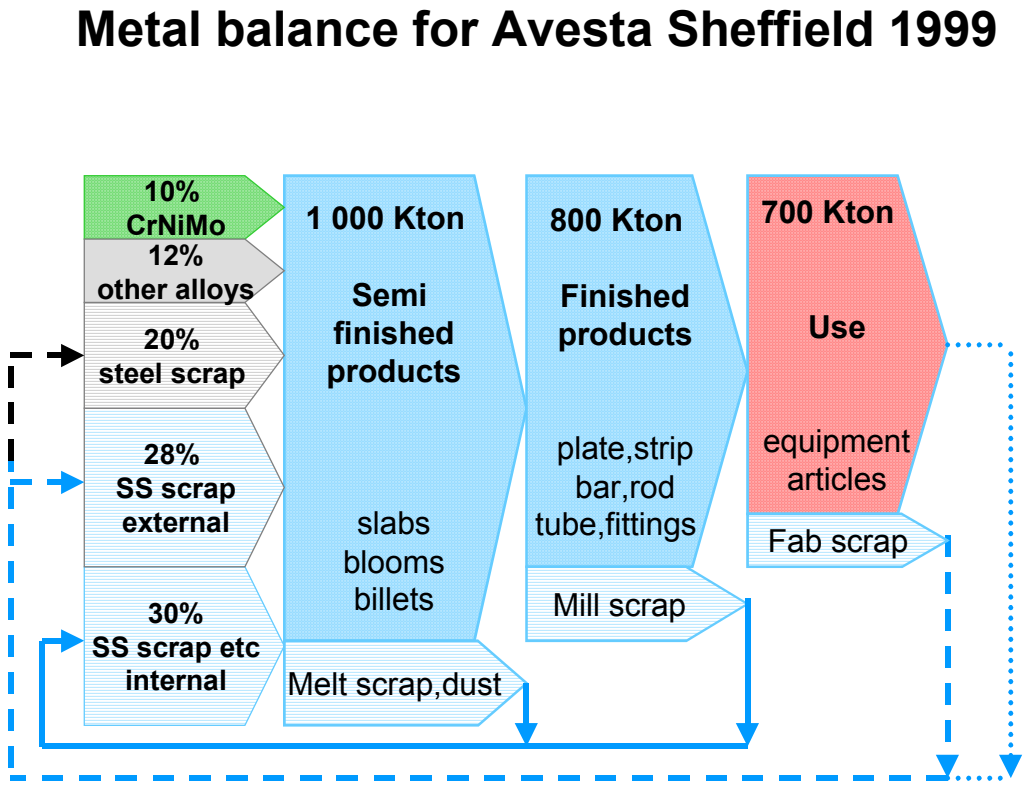
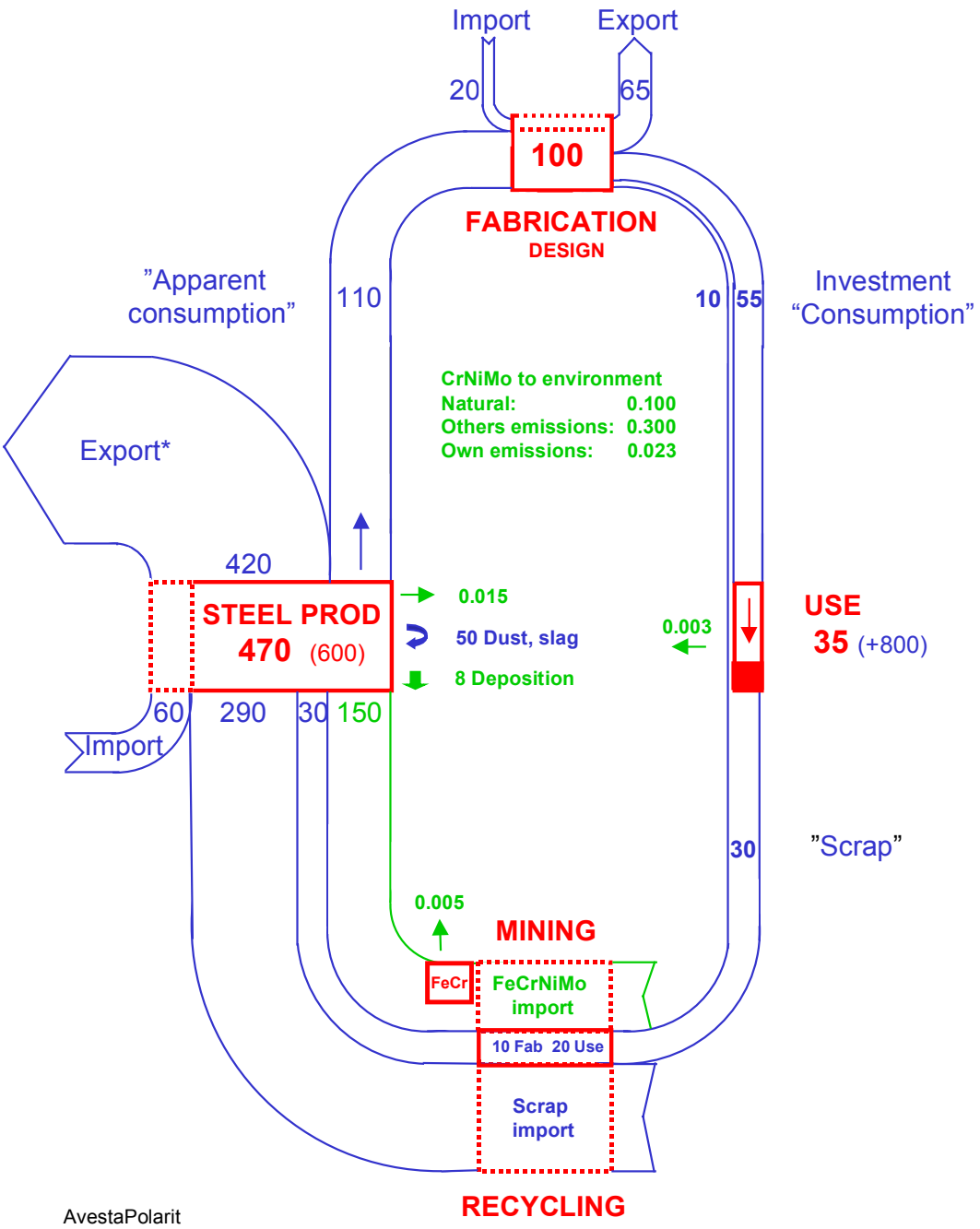


Figure 3


ECO CYCLE FOR STAINLESS STEEL IN SWEDEN
Model for 1990-96 in kton/year
Import
Export
20
65
100
FABRICATION
DESIGN
"Apparent consumption"
110
10
55
Investment "Consumption"
CrNiMo to environment
Natural: 0.100
Others emissions: 0.300
Own emissions: 0.023
Export*
420
STEEL PROD
470 (600)
0.015
50 Dust, slag
8 Deposition
0.003
USE
35 (+800)
60
290
30
150
Import
30
"Scrap"
0.005
MINING
FeCr
FeCrNiMo import
10 Fab 20 Use
Scrap import
RECYCLING
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