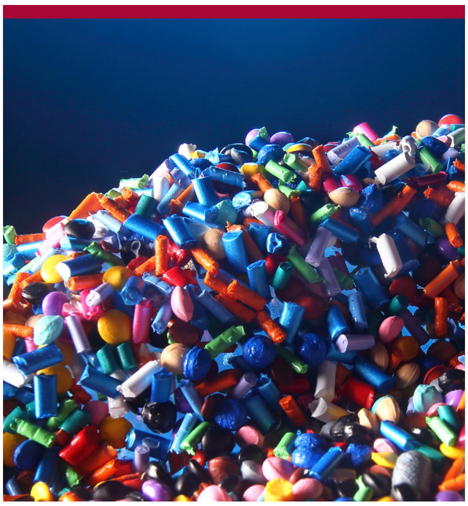
RE:SOURCE

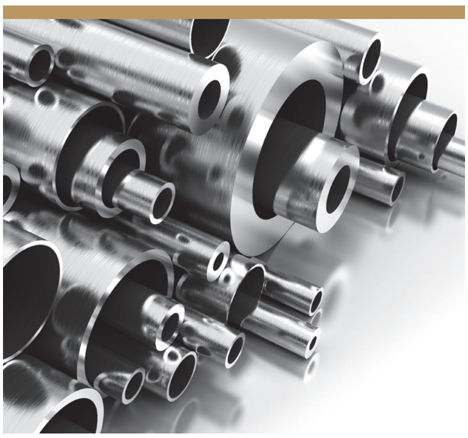
Återvinningsindustrierna

MATERIAL ECONOMICS

RETAINING VALUE IN THE SWEDISH MATERIALS SYSTEM

ENGLISH SUMMARY





PREFACE

The use of materials and material recycling has been discussed intensively for decades. And for good reason; there are many important issues related to our use of materials. What materials can and should be recycled, and what are the alternatives? What is the environmental impact of our use of materials? What policies are required and justified? The debate has been intensified as the greenhouse gas emissions from materials production has come into increasing focus, and as the potential for a more 'circular economy' has emerged as a theme in policy and business discussions.

So far, these discussions have been conducted in terms of tonnes, cubic meters, and environmental impacts. Public statistics, reports, and policies track volumes of materials (e.g., how many tonnes are diverted from landfill). Economic analyses have focused primarily on the costs and benefits of different policies. These are important issues, but they give far from the full picture. Economic and industrial opportunities of improved materials handling depend not on volumes, but on the economic value of materials. Conversely, neglecting quality and value all too easily gives the impression that we are more successful and 'circular' than is really the case.

This study takes a first step towards addressing these issues. It analyses the use of materials in the Swedish economy in monetary terms instead of tonnes and cubic metres. Key questions it seeks to answer include: *For each 100 SEK of raw material entering the Swedish economy, how much value is retained after one use cycle? What are the main reasons that material value is lost? What measures could retain more materials value, and how much could be recovered? What business opportunities arise as a result?*

These are ambitious research questions, and so far as we know, this is the first attempt to address them, in Sweden or internationally. But while this study leaves much still to explore, we believe the results show that the value perspective is highly relevant both for identifying business opportunities and to inform discussions about a more circular economy. There is economic potential in improving our handling of materials, in addition to environmental benefits. A better material system should be an attractive industrial vision. A study of these issues for the European economy as a whole is forthcoming.

The project has been carried out by Material Economics and the Swedish Recycling Industries under the RE:Source Strategic Innovation Program, and in collaboration with Electrolux, McDonalds, NCC, Ragn-Sells, SSAB, Stena Recycling, and Suez. Research guidance has been provided by Professor Göran Finnveden, Professor Mats Eklund, Professor Staffan Laestadius, Professor Anne-Marie Tillman and Professor Karin Markides. Many actors within Swedish business and research have also made valuable contributions. Any remaining errors are those of the authors.

SUMMARY

Every year large quantities of materials reach an end of use in the Swedish economy, with an estimated value of 55 billion SEK per year. These materials are, for instance, steel in buildings that are demolished, plastics from discarded packaging, aluminium in scrapped vehicles, used paper, and much more. Most of these can be recycled and made into new, secondary materials. This is a valuable resource, and its value corresponds to 1.2 % of GDP, or 12 000 SEK per household.

However, today's material handling causes three quarters of the material value to be lost after one use cycle. Only 13 billion (24 %) of the original value is retained as materials are recycled. As much as 42 billion SEK of materials value is therefore lost each year. Much of this value could be retained if materials were handled better. Measures to do so in turn give rise to business opportunities that can benefit both the economy and the environment.

Most of the loss of value results through the physical loss of materials in combination with downgrading of material quality. Much of the material is used only once: materials with an original value of 21 billion SEK are destroyed, lost, landfilled, or burned annually. Another 9 billion SEK worth are lost as materials are downgraded – mixed, contaminated, or otherwise lose important properties. Only a small share, 13 billion SEK is explained by the unavoidable processing costs of producing secondary materials (e.g, the step from scrap to steel, or fibre to paper). The picture is therefore one where in principle most of the value loss could be avoided.

KEY FINDINGS FOR MAJOR MATERIALS

PLASTICS

Plastic worth 10 billion SEK reaches end of use each year. As much as 84 % of this plastic is burned or landfilled. 16 % is recycled to new plastic, but then loses almost half of its original value, because quality deteriorates. Material recycling therefore retains only 8 % of the total original value of the plastic. Incineration of plastic has been a favoured approach, but it entails large value losses: even though more than 80% of end-of-use plastics is burned to produce energy, the value of that energy is just 5 % of the original material value. All in all, a mere 1.3 billion of the original 10 billion is captured. This is in sharp contrast to public statistics on plastics, which states that 53% of 'plastic waste' is recycled.

STEEL

is the most valuable material flow by far, as end-of-use steel worth 29 billion SEK becomes available each year. The value of steel scrap processed to new steel is an estimated 9 billion. The difference is partly explained by the fact that reworking scrap to new steel costs close to 9 billion SEK. However, another 12 billion of lost value arises through losses and downgrading. Some 7 billion is due to the physical loss of steel at various points of collection and processing – surprisingly high for a material that long has been recycled. Downgrading of quality results in another 5 billion in losses: 1.5 billion SEK because valuable alloying metals are not recovered; 1.5 billion SEK because high-grade steel is downcycled to less valuable structural steel; and another 2 billion through other factors that make scrap more expensive as an input to new steel production.

ALUMINIUM

worth 3.1 billion SEK reaches end of use annually. Of this, 1.2 billion SEK worth of value is retained. Material worth 0.9 billion is lost through lack of collection, process losses in recycling, and incineration as waste. Another 1.2 billion SEK is lost as initially pure aluminium is mixed and alloyed, or handled in ways that result in large additional upgrading costs. Overall, these losses paint a picture far from the common perception of aluminium as a material that entails a one-time investment in energy-intensive production, but can then be circulated and benefit the economy countless times.

OTHER MATERIALS

Extensive value losses also occur within a variety of other material categories and product groups. For example, we calculate a value loss for paper of 4 billion SEK per year. The reasons are mainly physical losses, lost fibre quality, and contamination. In the construction sector, very little demolition material is recycled except for metals, while losses during construction can amount to 15-20 % of the total materials used. Global figures for textiles indicate that 13 % of all textiles are recycled, but to low-value applications rather than to new textiles, and with significant loss of value as a result. There are many more examples from other material categories. Overall, the picture of large losses of value is a rule rather than an exception.

Overall, this shows that the Swedish economy is still much more 'linear' than the impression given by public statistics. Like in other countries, Swedish policy sets targets for a (weight) percentage of end-of-use materials to be collected for recycling. For example, public statistics report that the share collected for materials recycling is 53% for plastic waste, 48 % for demolition waste, and 70 % for packaging. These high numbers can give the impression that Sweden has come a long way towards circular material use. However, they are less informative as to how far materials recycling really reduces the use of primary materials: 1) They measure what is collected, rather than what ultimately becomes secondary material (31 % in comparison to 16 % for plastic, as above); 2) They report as 'material recycling' even very low-value uses (for example, when demolition materials from buildings are used as fillers in road construction); and 3) They do not take into account the loss of quality (for example 16 % of the volume of plastic preserves only 8% of the original value). Quality downgrading is particularly important, as it is often the root cause of low recycling volumes – the low value of secondary materials making it unprofitable to process and produce larger volumes of secondary materials. The value-based measures we develop in this report thus complement today's indicators and metrics. Not least, they are an important guide to how far we have come towards producing secondary materials that are capable of actually replacing primary materials – with the significant economic and environmental benefits that that this entails.

The downgrading of metals can create larger value losses, and preventing this is an important opportunity. For steel, a change is required to address the problems caused by the addition of copper to the steel stock. Swedish steel scrap contains 0.22 % copper on average, which is close to levels that would make it unsuitable for the production of important categories of steel. Currently, copper contamination is handled through downgrading to structural steel (which is more resistant to higher copper content) and through export to markets where scrap can be diluted with virgin steel. However, downgrading and dilution are not long-term solutions, particularly as the share of secondary steel is set to increase globally. Copper cannot be removed once added, and there is therefore large value in avoiding future degradation of the steel stock by preventing its addition in the first place. For aluminium there are similar issues. Today, highly alloyed and blended aluminium is used primarily to produce cast products used in the automotive sector. Today, cast aluminium is a high-quality material, and commands a price only slightly lower than primary aluminium. However, in a scenario with an increasing proportion of electric cars, demand could drop sharply, as electric vehicles lack many of the cast aluminium components found in today's cars. In this case, preventing the loss of value would require new sorting and circulation systems, with new business models for product manufacturers and materials companies.

Market failures and a 'linear' approach to product design explain much of today's loss of value. The reasons for value losses are found throughout the value chain of multiple product categories, as well as the way in which current legislation is designed. Manufacturing companies have few incentives to design products so that materials can be recycled, notwithstanding policies such as 'extended producer responsibility'. Products therefore impose a negative externality on secondary materials production. Negative external effects also arise in the production of primary materials, but are rarely fully reflected in raw materials prices. Regulations and targets can also steer in the wrong direction, causing materials to be used as low-value aggregates.

For all these reasons, policy will have a central role in achieving improved handling of materials. A first step could be to re-examine pre-existing policies. Current targets for materials collection could be reformulated to take aim at secondary materials production and material value instead. The current 'producer responsibility' framework creates weak or non-existent incentives, but could be steered towards some degree of individual rather than collective accountability, underpinned by new technology for the marking and tracking of products. Without the introduction of these types of policies, secondary material will continue to face an uphill battle. Today's playing field is far from level, and therefore other types of measures may also be required – such as requirements for the use of recycled material in new products. International cooperation will be crucial. Most products and materials are international commodities, and it is necessary to coordinate policies, first and foremost at EU level (the European Commission took an important first step with the 2015 Circular Economy Package, but its implementation now requires additional initiatives).

Companies can also act – even minor changes in how products are designed, produced and handled can make major contributions to preserving material value. Many companies have only just started to consider these issues. Product designers and company managers learned their craft in a linear economy, and have acquired few tools for thinking in circular terms. Manufacturing companies – the first users of materials – are therefore a key actor in improving the handling of materials. This also defines a clear agenda for companies seeking to make a contribution towards a more circular economy. The issue is relevant to several important value chains, among others:

- **Packaging:** Today's packaging is designed and handled in ways that causes large volumes of plastic and aluminium to be used only once. Even when recycled, packaging is a major source of materials mixing and contamination. This is an area with large potential: even minor changes could reduce costs of processing and promote retention of material value.

- **Electronics:** Recycling rates for electronics are much higher in Sweden than globally, but this product category nonetheless is a major technology development opportunity – both for product design and recycling processes. Key issues include increased re-use of components, and enabling the recovery of a wider range of materials (notably, rare metals).

- **Buildings:** Today, only metals are recovered when buildings are demolished. Many other construction materials are recyclable, including plastic, plaster, and mineral/glass wool, but are currently landfilled or burned. This is an area where Sweden lags behind other countries. Ultimately a new approach to the demolition process would be needed in order to turn buildings into a future 'materials bank', rather than merely a source of bulk aggregates.

- **Vehicles:** The dismantling of end-of-life vehicles leads to significant downgrading and loss of steel, aluminium, plastic, and several other materials. What originally were substantial material values often turn into a net-negative asset, as processing costs exceed the value that can be extracted. A step change in this product category would require an alternative to today's practice of shredding, supported by new product design, marking, and automation.

Digitisation is a key tool for more efficient materials handling, and innovation in this area a major industrial opportunity. A quiet technology revolution is already under way in several relevant areas. For example, LIBS-based sorting of steel scrap is now far cheaper than even a few years ago, while recent recycling plants incorporate ever more sophisticated sensors and automation for the processing of products from electronics to packaging. These are only the start of a digitisation trend that could be a major enabler of improved materials handling. Major opportunities include marking technologies, low-cost sensors, real-time tracking, distributed ledgers, and automation. Cumulatively, these have enormous potential to reduce the cost and increase the sophistication of secondary materials production.

A scenario of improved materials management can create large business opportunities over the next decades. This study has aimed to develop a detailed roadmap or vision for future materials use. Nonetheless, the analysis identified numerous measures that could reduce current value losses. To foster discussion, we therefore put these together in a scenario for how future improved material handling could look for three materials: steel, plastic and aluminium. Playing current practices forward to 2040 would see value losses of 20 billion SEK per year for these three materials. The measures we identify could recover more than half, or 11 billion SEK. Changing today's material system significantly will take time, and would require changes throughout the value chain. Although it is uncertain exactly what the outcome will be, we estimate that 3-4 billion SEK may come from changes in product design and choices of materials, where cleaner material flows from products designed for recycling could significantly reduce costs of processing as well as increase the revenue from higher quality outputs. An additional 3-4 billion SEK could be recovered through technology development and scale advantages in recycling systems. Bringing the recycling industry from today's fragmented and often small-scale methods to a substantially larger scale will lower costs, increase the possibility for specialisation, and enable uptake of new technology more rapidly. The last 2-3 billion is available through improved market functioning, including reduced uncertainty, more liquid markets, increased demand, and a more reliable investment climate. All in all, the opportunity to recapture value entails a variety of business opportunities for recycling companies as well as materials and manufacturing companies. Like any business activity, improving secondary materials production will require inputs, and therefore have costs. What the analysis shows is that significant revenues are available, which in turn can pay for the investments, inputs, and resources required to produce secondary materials. Opportunities vary between materials.

OPPORTUNITIES FOR EACH MATERIAL

PLASTICS: FOCUS ON ESTABLISHING CIRCULAR FLOWS FOR FIVE KEY PLASTICS.

We show what would eventually be required to recycle or re-use 55 % of plastic volumes (compared to 16 % today). The core of this is to close the loop for the five largest plastic types, which together account for 70 % of plastic use and are all highly recyclable. A circular scenario succeeds in retaining 40 % of the value – making 4 billion SEK per year available as revenues. Our analysis shows what it would take for recycling of plastics to be economically attractive in the long term; through changes in product design and material handling that increases quality; scale benefits and technology development, thus lowering the costs and reducing losses; and also through policies that reduce the price difference between new primary and recycled plastics. We believe that a focus on these five plastics helps reduce the complexity that often complicates discussions of how to manage plastics.

STEEL: SWEDISH INDUSTRY AS A LEADER IN A FUTURE HIGH QUALITY SECONDARY STEEL MARKET.

The biggest opportunity for Swedish industry is the further development of a market that closely matches end-of-use steel scrap with high-grade steel production. New technology is quickly improving the conditions for this opportunity, even as global steel markets are moving towards an increased proportion of secondary steel. Swedish steel production and scrap management are already world-leading, and have the opportunity to consolidate a position as a supplier of high quality secondary steel as the market grows. More sophisticated scrap management and markets will also be required to handle the problem of copper contamination.

ALUMINIUM: FOCUS ON ACHIEVING CLOSED LOOPS FOR ADDITIONAL PRODUCT GROUPS.

To preserve larger values in the future, more categories of product need to get to the point where aluminium cans are today, where the metal can be used for the same product repeatedly (a closed loop). Current practice in aluminium recycling is far from this point, and getting there will require a broad agenda starting with reduced volume losses, additional collection and deposit systems, product design for separate aluminium flows, better sorting of different aluminium qualities, and perhaps new methods to separate aluminium from other metals. Reducing downgrading becomes even more important in a scenario where demand for cast aluminium (which currently absorbs much of recycled aluminium) falls in the automotive sector.

OTHER MATERIALS AND PRODUCT GROUPS: SWEDISH COMPANIES AS LEADERS IN DEFINING FUTURE MATERIALS MANAGEMENT.

A key theme is the opportunities available through coordination across supply chains. Swedish companies have a great starting point. In addition to a strong materials industry, Sweden is home to a number of leading manufacturers across several important product groups – vehicles, textiles/fashion, furniture, workshop products, etc. – as well as holding a prime position in bio-based raw materials. There is therefore every opportunity to build industry collaborations aimed at reducing the value loss that now occurs in major product categories. The business case would be driven by recouping material values, but also by increasing customer expectations that companies contribute to improved resource efficiency.

There are strong links between maintaining material value and contributing to environmental objectives. The focus of this study has been on the economic aspects of end-of-use materials. However, a focus on materials value is also relevant for reducing the environmental impacts of material production and use. One connection is the role materials have in both Swedish and international climate targets. Emissions generated to serve Swedish demand for steel, aluminium, plastic and cement is estimated to be 13 million tons (”Mt”) of carbon dioxide (CO2) per year 2040, should the current production processes and recycling practices continue. In the value-retaining scenario described above, this falls by 4 Mt CO2 per year. Improved recycling has the benefit of cutting emissions from sources where emissions abatement is particularly difficult (e.g., mining, blast furnaces, etc.). It therefore contributes to Swedish policy objectives of ’net zero’ climate impact by 2045, and is an important complement to measures that reduce emissions from the material production processes. From the materials we focus on, plastic is particularly relevant to Swedish climate targets. For other materials, much of the CO2 footprint is in other countries, from which Sweden imports materials. By contrast, plastics use has a major impact on emissions also within Sweden’s borders, as the current practice is to burn most plastics for energy production – i.e., using plastic as a type of fossil fuel. Current practice would result in emissions of nearly 2 Mt CO2 per year by 2040. A transformation of plastics recycling as described above could halve these emissions.

Preserving material value is a realistic and exciting industrial innovation agenda. Perhaps the current transformation of the energy industry can provide inspiration: what was considered all but impossible only 10-15 years ago (cost-competitive wind power, solar power, battery technology, and electric cars) is now rapidly approaching reality, driven by a combination of technology development, legislation, ambitious corporate strategies, and innovation in business and financing models. A virtually CO2-free electricity system is clearly within reach in Sweden, with far lower costs than many had feared, and with significant scope for new value creation and industrial innovation. To embark in earnest on a journey towards a material system that retains the value of materials is as relevant a vision today as was the vision of a CO2-free electricity system 10-15 years ago. This is also an agenda in which Sweden has good prospects for leadership, even as the need for solutions in this area rapidly increases globally. Swedish entrepreneurship has great strengths in many relevant areas: a successful raw materials industry, a strong position in materials science, leading manufacturers in key product groups, well-functioning innovation systems, digitalisation capabilities, a proven track record of cross-industry collaboration, leading sustainability targets, and an internationally oriented economy. It is hard to imagine a better starting point. There is every reason for Swedish industry to take a leading role in developing the business models required to retain a greater share of material value.

55 BN SEK

Materials with a value of 55 billion SEK reach end of use each year in Sweden. This corresponds to 1.2% of Sweden's GDP or 12,000 SEK per Swedish household.

24 %

Only 24% of this material value remains after one use cycle. The loss of value amounts to 42 billion SEK each year, out of which 30 billion SEK remains after accounting for the process costs that are hard to avoid.

LINEAR ECONOMY

The Swedish economy therefore is still significantly more linear than implied by public statistics. Official numbers suggest recycling of 75-95% of steel, 50% of plastic, 50% of demolition waste, etc. – whereas the retained value is only 24%.

11 BN SEK

in a 2040-perspective, 11 billion SEK per year of today's lost material value can be recovered. It is a realistic and exciting industrial innovation agenda for Sweden to significantly increase the proportion of the value of material that is preserved.

87 %

LOSS OF PLASTICS VALUE

Today, we only maintain ~ 15% of the original value. This is mainly due to the fact that the majority of the plastic is incinerated for energy recovery, and the recycled plastic is of significantly lower quality and value than newly manufactured plastic.

58 %

LOSS OF STEEL VALUE

Today, only ~40% of the value of steel is maintained, due to volume losses during collection and production, as well as the downgrading of the quality of steel.

62 %

LOSS OF ALUMINIUM VALUE

Aluminium looses over 60% of its value during one cycle of use, mainly due to downgrading, but also due to the fact that 30% of aluminum is not recycled.

A more circular material system is also central to achieving climate goals. Without change, today's use of steel, aluminum and plastics will give rise to 13 Mt CO2 per year, which is more than 20% of Sweden's total emissions in 2015. In our circular scenario, this is reduced to 9 Mt.

13 MT CO_2

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The report takes a value perspective on materials use It analyses the use of materials in the Swedish economy in monetary terms instead of tonnes and cubic metres. Key questions it seeks to answer include: For each 100 SEK of raw material entering the Swedish economy, how much value is retained after one use cycle? What are the main reasons that material value is lost? What measures could retain more materials value, and how much could be recovered? What business opportunities arise as a result?

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