Slutrapport för projekt

Preserving value in EU industrial materials

Projektperiod: April 2019 – Oktober 2020

Projektnummer: 6524-06

Med stöd från

VINNOVA Sveriges innovationsmyndighet

Energimyndigheten

FORMAS

Strategiska innovations-program

Datum
2020-10-05

Dnr
[Klicka här och skriv]

Projektnr
6524-06

Ett värdebeständigt europeiskt materialvärdesystem

Preserving value in EU industrial materials

Titel på projektet – svenska Ett värdebeständigt europeiskt materialvärdesystem
Titel på projektet – engelska Preserving value in EU industrial materials
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Nyckelord: 5-7 st Cirkulär ekonomi, återvinning, material, stål, plast, aluminium, industri

Med stöd från
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Energimyndigheten
FORMAS
Strategiska innovationsprogram

Preface

Material use and material recycling have been discussed for decades in Europe. And for good reasons – there are many important questions related to our use of materials: What materials should be recycled, and how? What are the environmental benefits of increased recycling? Which policies regarding waste and recycling are reasonable? The debate has intensified the last years, not least due to the increased focus on climate change mitigation and on establishing a 'circular' economy; intense work is going on both in the policy sphere and in industry to make our material use more sustainable.

So far, the debate has primarily been held in terms of tonnes, cubic metres, and environmental impact. Public statistics, most academic research and industry reports discuss in volume terms, and 'material flow analysis' is one of the most commonly used tools. This is all, of course, highly relevant, but a volume perspective also leaves important questions unanswered. For instance, how big is the quality downgrading effect in different material flows? How much primary materials production can actually be replaced by recycled materials with today's recycled materials quality? How close to a 'closed-loop' materials system is Europe actually? Only looking at what share of the material volumes come back may lead users of such statistics to believe our material use is more circular than it actually is.

This report takes a step towards painting a more complete picture. The report takes an economic value perspective on material flows and assesses Europe's use of steel, plastics and aluminium in terms of Euros instead of tonnes. The 'exam questions' we ask ourselves are: *If a 100 Euros of raw materials is entered into the European economy, how much economic value is retained after one use cycle? What are the main reasons that material value is lost? How could more value be retained? What business opportunities arise as a result*[1]*?"*

These are ambitious research questions, and as far as we know this is the first broad European investigation of materials value retention. Hence, this report should be read as a piece of initial research, which needs to be followed by much more research. There are many methodological and statistical issues to refine, which may also change our estimates of value retention. But we believe the report shows that a value-based perspective has important new insights to offer when discussing what Europe's future materials system should look like and how it can be made more circular and environmentally sustainable.

This study was carried out by Material Economics on behalf of Climate-KIC and RE:Source between March 2019 and June 2020. It builds on a previous similar study of the Swedish material system published in 2018 with the support of RE:Source and the Swedish Recycling Industries' Association. We would like to thank all the numerous experts who have provided input to this report.

[1] This means the report only looks at a subset of the circular economy, namely *materials* circularity and retaining the value in materials. The report does not assess *product* circularity opportunities. Take a car as an example: The report does not look at opportunities to re-use or re-manufacture individual components of a car, or the entire car. Instead, this report focuses on what happens to the steel, plastics and aluminium that the car is made from, and asks questions about why those materials, which in principle can be recycled many times, are worth less to the next user.

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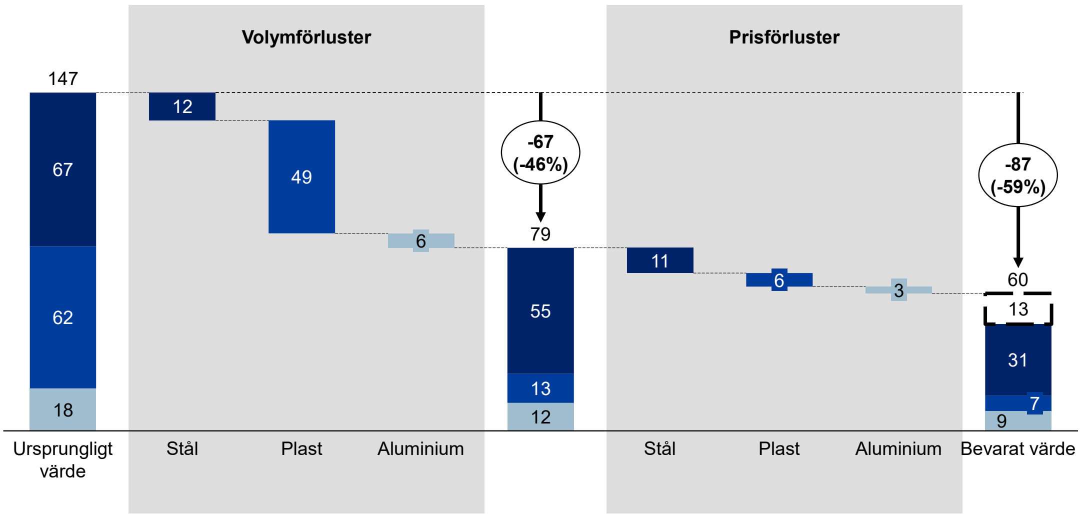
Sammanfattning

Varje år faller 180–190 miljoner ton stål, plast och aluminium, med ett ursprungligt värde på €140–150 miljarder, ur EU:s ekonomi efter att ha fyllt viktiga roller i fordon, byggnader, produkter och förpackningar. Dessa material är nästan alla tekniskt återvinningsbara (uteslutande t.ex. termoplaster) och om allt detta material skulle återvinnas skulle de kunna leverera så mycket som 82% av EU:s totala efterfrågan, även efter att ha man redovisar för oundvikliga förluster i återvinningsprocessen. Med andra ord kan EU nästan tillgodose hela sitt behov inom dessa tre kategorier genom återvunnet material. Om kvaliteten på dessa återvunna material liknade kvaliteten på jungfruligt material skulle det ursprungliga värdet också bibehållas. I monetära termer motsvarar det ursprungliga värdet cirka €340 per EU-invånare eller lika mycket som hela den europeiska bilindustrins exportintäkter (€136 miljarder 2019). Dessa tre material har valts eftersom de är de tre största industriella materialflöden i Europa där majoriteten av materialet är tekniskt återvinningsbart nästan ett oändligt antal gånger. Detta är att jämföra med cement, som är extremt utmanande och ofta omöjligt att återvinna, eller papper som bara kan återvinnas ett fåtal gånger.

Idag återstår bara cirka 41% av detta ursprungliga materialvärde efter en användningscykel. Totalt uppgår förlusterna till €87 miljarder per år. I praktiken, när dessa material säljs som återvunnet material, är deras marknadsvärde cirka €44 miljarder. Ytterligare €2 miljarder av det ursprungliga värdet fångas upp i avfallsförbränningsanläggningar och det finns cirka 13 miljarder euro i oundvikliga upparbetningskostnader (t.ex. omsmältning). Skillnaden, 87 miljarder euro per år i hela Europa, är värdeförluster längs användnings- och återvinningscykeln. Detta är tankeväckande: Varför skulle mer än hälften av det ursprungliga materialvärdet gå förlorat för material som tekniskt kan återvinnas utan någon större förlust av kvalitet? Vad säger det om Europas cirkularitet?

Bild: Varje år, förloras €87 miljarder materialvärde i användningen av stål, plast och aluminium

Värdeförluster i materialvärdessystemet
€ miljarder, 2016



Källa: Material Economics modellering som beskrivs i sektorkapitlen

Värdeförlusterna kan delas in i två breda kategorier: volymförluster och prisförluster (eller kvalitetsförluster). För det första återvinns en stor del av använda material inte utan deponeras eller används som bränsle (plast); vissa går förlorade i återvinningsprocesser; andra kommer aldrig ens in i avfallssystemet. Dessa volymförluster motsvarar €67 miljarder av den totala värdeförlusten, eller 77%. För det andra försvinner ytterligare €20 miljarder i värde (23%) eftersom vissa återvunna material är av lägre kvalitet än deras primära motsvarigheter. Viktiga orsaker till dessa pris- och kvalitetsförluster inkluderar blandning av olika fraktioner, "ofrivillig" legering av metaller och olika typer av föroreningar. Detta gäller särskilt för plast, och det är en av de främsta orsakerna till dess relativt låga återvinningsgrad (~ 10%, jämfört med 81% respektive 66% för stål respektive aluminium) och det lägre priset för återvunna polymerer. Pris- och kvalitetsförlusterna är dock mycket viktigare än dessa siffror antyder, eftersom de låga priserna gör det oekonomiskt att samla in och bearbeta material, vilket i sin tur leder till lägre återvinningsvolymer.

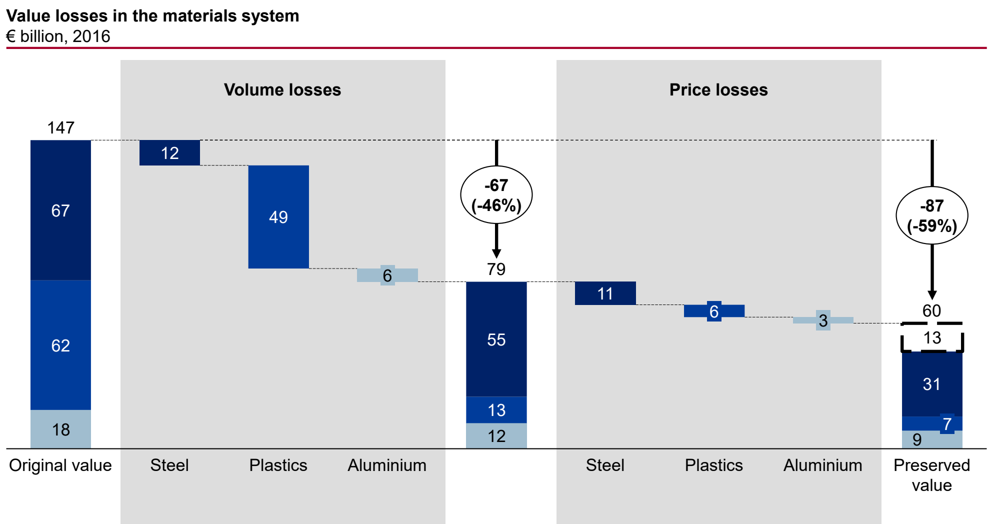
Väldigt olika mönster av värdeförlusterna för olika material. För stål och aluminium återvinns de flesta volymerna, men legering och förorening gör användningen av det återvunna materialet annorlunda än för oskuldsmaterial (det som ibland kallas "open loop"-cirkularitet), medan för plast endast en liten andel av volymerna förvandlas till en ny plastprodukt.

Summary

Each year, 180–190 million tonnes of steel, plastics, and aluminium, with an original value of €140-150 billion, falls out of the EU economy, after fulfilling essential roles in vehicles, buildings, products and packaging. Materials in these three categories[2] are almost all technically recyclable (barring e.g. some plastic thermosets), and if *all* these materials were recycled, they could supply as much as 82% of total EU demand in the same categories, even after accounting for unavoidable losses in the recycling process. In other words, the EU could almost meet its entire need within these three material categories from recycled materials. If the quality of these recycled materials was similar to that of virgin materials, the original value would also be maintained[3]. In monetary terms, the original value corresponds to approximately €340 per EU inhabitant or, as another comparison, it is similar in size to the export revenues of the entire European automotive industry (€136 billion in 2019).

Today, only about 41% of this original material value remains after one use cycle. In total, the losses amount to €87 billion per year. In practice, when these materials are re-sold as recycled materials, their market value is approximately €44 billion. Another €2 billion of the original value is captured in waste-to-energy incineration plants, and there are about €13 billion in unavoidable reprocessing costs (e.g. remelting). The difference, €87 billion per year across Europe, are value losses along the use and recycling cycle. This is thought-provoking: Why should more than half of the original material value be lost for materials that technically can be recycled without any major loss in quality? What does that say about Europe's circularity?

Exhibit: Each year, €87 billion of materials value is lost in the use of steel, plastics and aluminium



Source: Material Economics modelling as described in sector chapters

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2 These three materials were chosen as they are the three largest industrial materials flows in Europe that are technically recyclable many times.

3 For steel and aluminium, we define original value as the value per ton virgin steel slabs and aluminium ingots, respectively, and for plastics as the value per ton virgin plastic resins.

The value losses can be divided into two broad categories: volume losses and price (or quality) losses. First, a large share of the end-of-life materials are not recycled, but rather put in landfills or used as fuel (plastics); some are lost in recycling processes; others never even enter the waste collection system. These volume losses represent €67 billion of the total value loss, or 77%. Second, because some recycled materials are of lower quality than their primary counterparts, another €20 billion in value is lost (23%). Key reasons for these price and quality losses include mixing of different fractions, 'involuntary' alloying of metals, and different types of contamination. This is particularly true for plastics, and it is one of the main reasons for its relatively low recycling rates (~10%[4], compared with 81% and 66% for steel and aluminium, respectively) and the lower price of recycled polymers. The price and quality losses, however, are much more important than these numbers suggest, as the low prices is what makes it uneconomical to collect and reprocess some of the materials, which in turn leads to the volume losses. If we first calculated the price losses, these amount to €48 billion annually (55%), while the volume losses amount to €39 billion annually (45%). During the rest of this report, we will first look at volume losses and then price losses, as many of our speaking partners have found that more intuitive way of explaining the value losses.

Very different value loss patterns across the different materials. For steel and aluminium, most of the volumes are recycled, but alloying and contamination make the possible uses of the recycled material different from that of virgin materials (what is sometimes referred to as 'open loop' circularity), whereas for plastics only a small share of the volumes are turned into a new plastic product.

[4] Note: The plastics recycling rate includes removing exports of plastic waste, which was not done for the aluminium and steel rates as plastics can generally be considered a one way waste flow while aluminium and steel scrap are essentially internationally traded commodities

Introduction and background

Making good use of materials is a decades-old challenge that involves both economic, environmental and geopolitical considerations. On one hand, of course, industrial materials play a crucial role in providing many essential products and services, and materials-related industries are large employers in many countries. As an example, the European plastics industry alone employs over 1.6 million people.

But there are also less desirable aspects of our material production and use: Materials production represents about ~10% of greenhouse gas (GHG) emissions[i] from EU industry. Water use and littering (e.g. plastics in the ocean) are other areas of concern.

The concept of a 'circular economy'[ii] has emerged as a potential solution, emphasizing both the economic and environmental opportunities in a better use of products and materials. Circular economy has gained significant traction over the past 5-10 years in policy, business and civil society. The European Commission has introduced Circular Economy strategies and action plans to support the transition in the EU, as have many Member States.

Why an economic value perspective on materials use?

Materials recycling is a main feature of a circular and low-carbon economy. Recycling is today measured and analysed primarily in volume terms, looking for instance at the share of steel, aluminium and plastics collected for recycling, or using material flow analysis ('MFA') to trace a tonne of different materials through the economy and assessing what happens to it. As a result, we would argue that the volume aspects of Europe's material use are today relatively well understood and well known.

However, such volume-focused assessments do not capture information about the quality of recycled materials. Quality, in turn, determines what applications the recycled material can actually be used for and to what extent it can replace primary demand, a precondition for truly circular material flows. If the material that comes back is significantly downgraded and can only be used for a different set of applications than the primary material, it is hard to argue that the material use is circular.

In this report, we explore whether an economic value-based approach can yield additional insight into Europe's material use. The 'exam questions' we ask ourselves are: *If a 100 Euros of raw materials is entered into the European economy, how much economic value is retained after one use cycle? What are the main reasons that material* *value is lost? How could more value be retained? What business opportunities arise as a result*[5]*?"*

In a way, one could call this approach a high-level economic MFA. During the work, we have identified a few important advantages of such an approach: 1) It starts to capture the important quality aspects mentioned above, by using the market price of the recycled material as a proxy for quality. If the quality was similar, it is fair to assume the price would also be similar, 2) Describing the material flows in economic terms makes transparent and highlights all the industrial and economic opportunities inherent in a more circular material use, and makes it easier to compare and prioritize between opportunities. There are, of course, also drawbacks: 1) Market prices of secondary materials do not only reflect the quality of Europe's material use and recycling system, they are also impacted by the price of virgin materials, as virgin and recycled materials often compete in at least some applications. Raw material prices are often volatile, and this creates 'noise' in our analysis. 2) Price data is harder to get hold of than volume data, and often available only at an aggregated level. For these reasons, we in no way suggest an economic-value based approach can or should replace volume-based approaches. Instead, we see them as complementing each other.

The research questions above are ambitious. Hence, this report should be read as a piece of initial research, which needs to be followed by much more research. There are many methodological and statistical issues to refine, which may also change our estimates of value retention. But we believe the report shows that a value-based perspective has important new insights to offer when discussing what Europe's future materials system should look like and how it can be made more circular and environmentally sustainable.

Methodology used

The methodology we have used is explained step-by-step in Exhibit 5. Let us here make a few remarks at a higher level about why this methodology was chosen, data sources, and advantages and drawbacks.

First, it is important what we define as the starting point of the analysis, the 'original value' in Exhibit 1. For the three materials, we start from the value of virgin slabs for steel, virgin ingots for aluminium, and virgin resins for plastics. In principle, in a perfectly circular system, this original value would be recreated when recycled materials come back: scrap steel is remelted to slabs, scrap aluminium to ingots, and recycled plastics to resins. In reality, as the following chapters will show, the recycled versions are worth less. Sometimes, this is due to intentional alloying or

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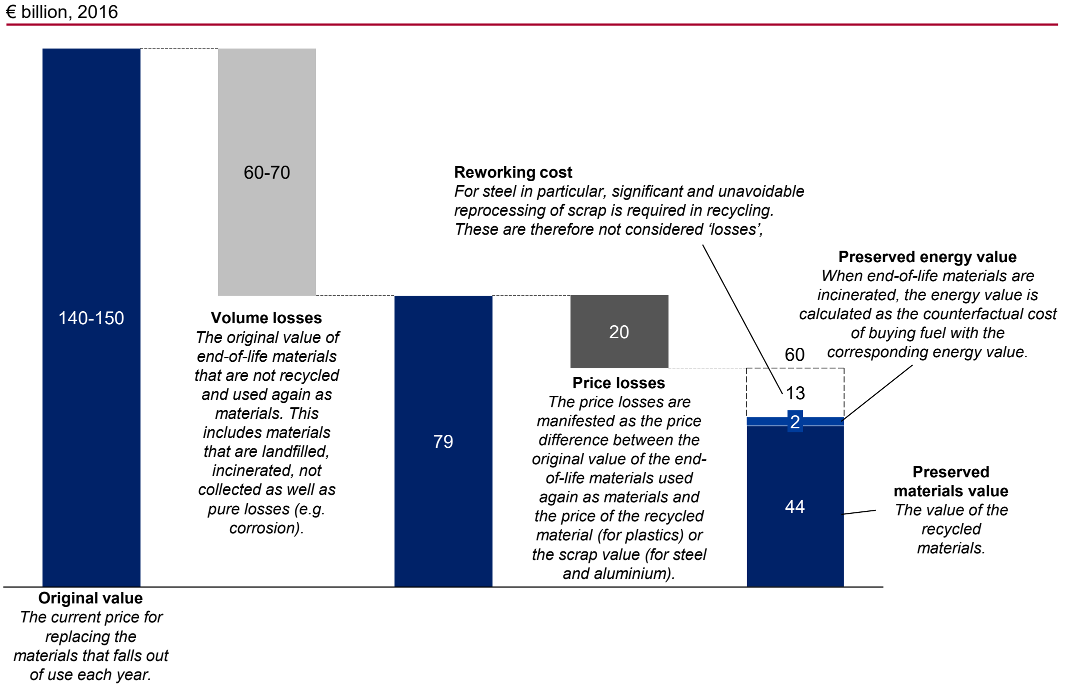
[5] This means the report only looks at a subset of the circular economy, namely *materials* circularity and retaining the value in materials. The report does not assess *product* circularity opportunities. Take a car as an example: The report does not look at opportunities to re-use or re-manufacture individual components of a car, or the entire car. Instead, this report focuses on what happens to the steel, plastics and aluminium that the car is made from, and asks questions about why those materials, which in principle can be recycled many times, are worth less to the next user.

additives, done to give the material specific desired properties, but also in these cases it is interesting to understand what this alloying and additives mean for the recyclability and for the next user. In many cases, the value loss is also unintentional, driven by mixing effects, downgrading, and information losses along the use cycle. This original value is possible to estimate quite accurately from public statistical sources and market price data. We adjust for imports and exports throughout the analysis.

Second, we look at what the recycled versions of slabs, ingots, and resins are worth. There is good volume data available, and also price indices for different qualities of metal scrap and recycled plastics, so the 'preserved materials value' can also be calculated with reasonable accuracy. This allows to calculate the total value loss, as the difference between the 'original value' and the 'preserved value'.

Third, we disaggregate and try to explain where and why the value losses occur. Disaggregating the value loss into volume effects (which share of the materials come back at all?) and value effects (how much less is the recycled material worth per tonne?) is a very natural first step. However, since volume and price are mutually dependent, the order in which one subtracts the volume and price effects matters. We have chosen to first subtract volume effects and then price effects, simply because it is easier to explain this approach and it has felt more natural to many of our speaking partners. But we note that this risks downplaying the importance of quality downgrading – it is in many cases the low quality that causes the recycled material's market price to be so low that it is not economically worthwhile to recycle it. Beyond this basic price-volume split-up, our disaggregation analysis becomes a qualitative analysis as much as a quantitative: It involves understanding why different types of mixing and alloying effects occur, what part of them are voluntary and not, and what the value effects of each are.

Exhibit 1 Methodology for estimating material value losses



Source: Material Economics modelling as described in sector chapters

The methodology can be summarised in six steps, as described below:

1. **Focus on three large material categories:** This analysis covers three materials – steel, plastics and aluminium – but the methodology is in principle applicable also to other materials such as paper and board, textiles, cement. It is important to note that the focus of this analysis is on the value of *materials*, meaning that it does not look at *product* values and product circularity opportunities. Take a car as an example: The report does not look at opportunities to re-use or re-manufacture individual components of a car, or the entire car. Instead, we focus on what happens to the steel, plastics and aluminium that the car is made from, and ask questions about why those materials, which in principle can be recycled many times, are worth less to the next user.

2. **Analyse materials that fall out of use:** The material flows that are considered in this study are the end-of-life flows of steel, plastics and aluminium in the EU. These materials come from products, components, buildings, packaging, etc. that reach the end of their useful lives every year. For example, they include aluminium and steel in scrap cars, plastics in packaging that is discarded, and the steel from demolished buildings. Materials that fall out of use, in principle, become available for recycling or other forms of reuse.

3. **Estimate the original value of the end-of-life materials (€140-150 billion):** To understand the value losses that arise from our current use of materials, the starting point of the analysis is the price of a corresponding amount of primary materials. This reflects the value these materials would have if no volume losses or quality degradation occurred during their use, as well as the cost of replacing the same volume of materials at today's prices. For steel and aluminium, we define original value as the value per ton virgin steel slabs and aluminium ingots, respectively, and for plastics as the value per ton virgin plastic resins. For most of the materials, we have used 2016 as a basis year for prices, as this is the year for which the most complete data are available.

4. **Calculate the preserved value (~€46 billion):** The next step of the analysis is to investigate what happens to end-of-life materials once they become available again. There are a range of different potential fates for end-of-life steel, plastics and aluminium, including but not limited to recycling, incineration and landfill. Different treatment methods, in turn, lead to widely differing amounts of *preserved value*, defined as the market value of the material in its next use, be it as a material or as fuel.

   a. **Preserved materials value (€44 billion):** We define the preserved materials value as the value of secondary or recycled materials. For example, the preserved value of recycled plastics is the market value of recycled polymers made from end-of-life plastics that have been collected, sorted and reprocessed into recycled plastics. For plastics waste exported for recycling outside the EU, we let the export value of the plastics represent the preserved value. For steel and aluminium, the preserved value is instead the value of the collected scrap, as this is what is traded globally and has clear market prices. Unavoidable reworking costs are separately accounted for, as described in step 6.

b. **Preserved energy value (€2 billion).** The other value-preserving end-of-life destination for materials is energy recovery (landfill, incineration without energy recovery, and corrosion and other losses do not recover any value). The preserved energy value is defined as the counterfactual cost of buying fuel with the corresponding energy value. Out of the three investigated materials in this study, only plastics are used for energy recovery in a major way.

5. **Analyse value losses (€87 billion):** The difference between the original materials value and the preserved value is the *value loss* or *value leakage.* We go on to analyse the causes for this value loss and identify opportunities to preserve more value in the materials system. The value losses can be divided into two broad categories.

a. **Volume losses (€60-70 billion):** All end-of-life materials that are not recycled into new materials are considered volume losses, as these materials go to other, often lower-value, uses. The case in point for volume losses is plastics, a significant share of which are incinerated rather than recycled into useable plastics. Other examples include steel that is not collected or that is lost, or aluminium that is not sorted from other waste before incineration (for example, in electric and electronic equipment).

b. **Price losses (€20 billion):** Price losses occur when the quality of materials are downgraded in various stages of its use cycle, including in product design and manufacturing, in waste collection, or in the recycling process. A lower price is a good indication of limitations in the use of recycled materials.

6. **Reworking costs (€13 billion):** For some materials, significant costs for reworking waste into new materials are incurred. For steel, costs arise in the remelting of scrap in an electric arc furnace (EAF). These costs are displayed separately, as they are close to unavoidable.

Project procedure

This report was developed through a combination of extensive literature reviews on different areas, several expert interviews with relevant stakeholders in the different industries, and modelling to develop results. Further details on the methodology used can be seen in the introduction of the report.

Material Economics developed the entire report from start to finish, including initial research, modelling, and writing of the report. In addition, some editorial support was given by Marion Davis and design support by Ludvig Siggelin.

Results and discussion

Today, only about 41% of this original material value remains after one use cycle. In total, the losses amount to €87 billion per year. In practice, when these materials are re-sold as recycled materials, their market value is approximately €44 billion. Another €2 billion of the original value is captured in waste-to-energy incineration plants, and there are about €13 billion in unavoidable reprocessing costs (e.g. remelting). The difference, €87 billion per year across Europe, are value losses along the use and recycling cycle.

The value losses can be divided into two broad categories: volume losses and price (or quality) losses. First, a large share of the end-of-life materials are not recycled, but rather put in landfills or used as fuel (plastics); some are lost in recycling processes; others never even enter the waste collection system. These volume losses represent €67 billion of the total value loss, or 77%. Second, because some recycled materials are of lower quality than their primary counterparts, another €20 billion in value is lost (23%). Key reasons for these price and quality losses include mixing of different fractions, 'involuntary' alloying of metals, and different types of contamination. This is particularly true for plastics, and it is one of the main reasons for its relatively low recycling rates (~10%, compared with 81% and 66% for steel and aluminium, respectively) and the lower price of recycled polymers. The price and quality losses, however, are much more important than these numbers suggest, as the low prices make it uneconomical to collect and reprocess materials, which in turn leads to the lower recycling volumes. If we instead first calculate the price losses, these amount to €48 billion annually (55%), while the volume losses amount to €39 billion annually (45%). During the rest of this report, we will first look at volume losses and then price losses, as that is a more intuitive way of thinking about the value losses.

Very different value loss patterns across the different materials. For steel and aluminium, most of the volumes are recycled, but alloying and contamination make the uses of the recycled material different from that of virgin materials (what is sometimes referred to as 'open loop' circularity), whereas for plastics only a small share of the volumes are turned into a new plastic product.

- For ***steel***, the largest of the three material flows and the most recycled, 66% of value is preserved after one use cycle. The fact that most of the steel (81%) is recycled is probably well known to many readers. What is perhaps less well known is the quality downgrading: Steel is often alloyed with small volumes of other metals (often highly expensive metals) to give it specific properties. The first time these alloy metals are added, they are 'tailormade' to produce the desired material properties. In subsequent use cycles, however, they often become a problem, reducing the value of the scrap steel. Copper is a specific concern: It often gets unintentionally mixed with steel in the scrapping process (e.g. electric cables in a scrapped car or household appliance) and negatively impacts the steel's strength. Copper is also very hard to separate from the steel once it has been mixed-in. As a result, secondary steel is often used for lower-value applications, for instance construction steels.
- For ***aluminium***, 50% of the value is preserved after one use cycle. The effective average volume recycling rate is 66%, due to collection losses (e.g. in packaging and construction) as well as losses in the recycling processes. However, many aluminium products are also alloyed to give the right material properties, but these alloyed materials are then often not re-used into the same product again. Instead, after one use cycle, much of the volume becomes cast aluminium, a less valuable product with motor blocks in cars as its main application. This is a downgrading effect – the potential applications for cast aluminium are distinctly different from virgin aluminium – which is also reflected in the price difference between virgin and recycled aluminium.
- For ***plastics***, contamination, mixed polymer grades and colours, and the mechanical recycling process itself all contribute to quality and volume losses in recycling, to the extent that only ~11% the value is retained[6].

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[6] Note this is slightly higher than the recycling rate as €2.4 billion value is recovered from energy recovery in waste incineration, meaning the value recovery is slightly higher than the recycling rate

Conclusions, impact and next step

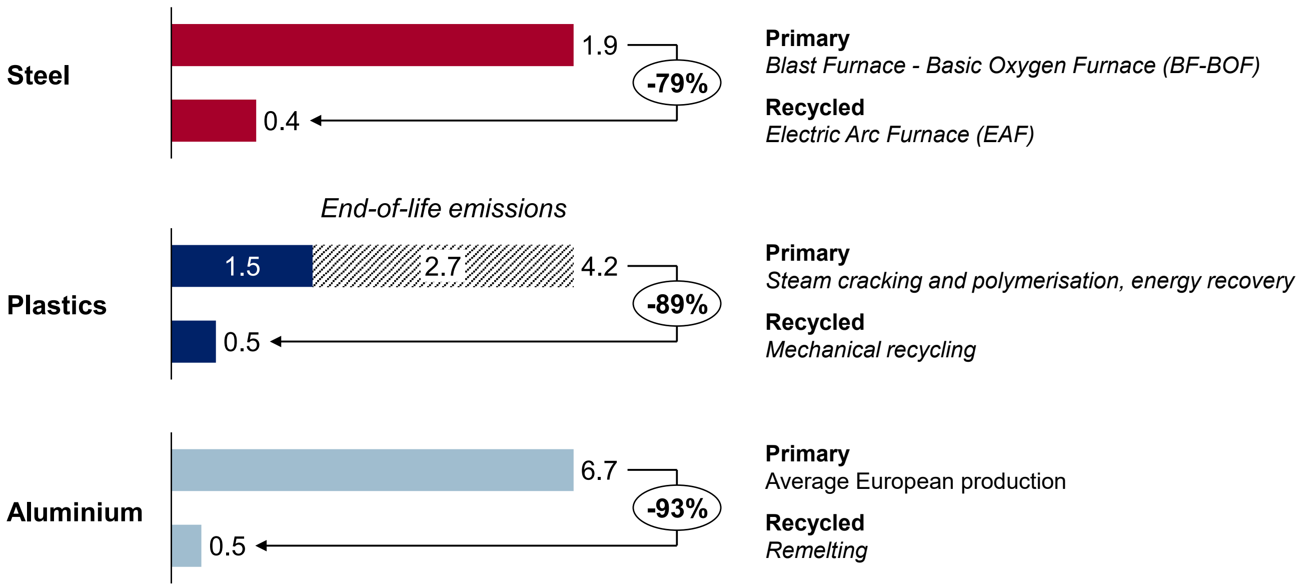
Addressing these value losses is likely a major opportunity for Europe, economically, environmentally, and geopolitically. Moving in the direction of increased materials value retention seems very consistent with the EU's Circular Economy Action Plan, and with the ambition in many Member States to move towards a more circular economy. While each potential policy should of course be carefully assessed in its own right, with both advantages and disadvantages analysed, there are a few overall arguments that suggest increased materials value retention is indeed an attractive opportunity for Europe.

- **Increased materials value retention could become a major business and industrial opportunity, in keeping with the strengths of European industry**. A closed-loop system is a major business opportunity for recyclers, industrial materials users, recycling equipment providers, and other stakeholders. It will never be possible to eliminate all the €87 billion of value losses, given the billions of pieces of materials that are placed on the market yearly and the natural losses due to processes such as corrosion, but even a partial recovery represents significant value[7] For example, circular business models such as take-back schemes and subscription-based business models, together with design for recycling, can enable higher-value recovery and tighter material loops. Partnerships along the value chain and improved waste management and recycling technologies can increase the quality of recycled materials. All these opportunities have strong synergies with digitalisation, as new sorting technologies, tagging and tracking of materials, etc., make it possible to increase volume and quality, while decreasing cost. Moving in this direction will also give rise to significant green job creation across Europe, as imported primary materials are replaced with European recycling and reprocessing. This is especially important today given COVID-19.
- **Increasing the circularity of steel, plastics and aluminium can help the EU significantly in meeting its climate targets.** The production of these materials today accounts for ~10% of total EU CO_2 emissions from industry and energy, and materials recycling is 80-93% less CO_2-intense than primary materials production. Recycling also shifts CO_2 emissions from hard-to-abate sources such as mining, oil and gas extraction; blast furnaces; and steam crackers, to sources such as electricity and low- or medium-temperature heat production that are easier to decarbonise.

[7] Note that the €87 billion of value losses should be thought of as the total *revenue* opportunity. Better recovery and reprocessing of these materials will also carry a *cost*, and for many fractions the costs today outweigh the revenue. But with new business models, better product design, new recycling technologies, and new policy a larger and larger share of the €87 billion will be possible to profitably address.

Exhibit 2 Recycled materials are ~80–95% less CO_2-intensive than primary production

CO_2-intensity of primary and recycled materials production
tCO_2/t material



Sources: Material Economics modelling in Industrial Transformation 2050 and Circular Economy reports, World Aluminium

- **Building a stronger, more circular economy for industrial materials will also enable a more resilient EU industry that is less dependent on imports of potentially more polluting primary production.** Europe today exports significant amounts of used materials and instead imports primary materials from abroad. Changing this could both improve the predicament of the often challenging economic environment faced by European primary producers by developing a new source of local raw materials, and strengthen the long term resilience of the industry through reduced reliance on imports. For example, the trend towards increased electric arc furnaces in steel production means that having sufficient access to steel scrap will become a strategically important aspect for European steel producers.
- **Possible drawbacks include increased reverse logistics flows, increased complexity and cost in sorting, and transition costs.** No change of this scale is possible without any drawbacks. In this case, the primary drawbacks are likely increased traffic and reverse logistics flows, and increased costs of recycling.

Policy will need to play a major role if Europe wants to capture more materials value. This report has not analysed in detail what policy interventions are needed for Europe to significantly increase materials value retention. However, it is clear that policy will have to play an important role; the changes required are often too systemic for any single company to capture by itself. For instance, the effects of improved product design choices are often seen many years later and in completely different industry sectors, improved scrap sorting likely needs to be based on industry-wide standards, the toxicity issues that plague plastics recycling need an industry-wide answer, et cetera. A possible way forward could be to take the materials value perspective explicitly into account next time Europe reviews its policies for these materials, or for the main products where they are used. Important policy areas include Enhanced Producer Responsibility ('EPR') frameworks, product design frameworks, and waste frameworks. Of course, the competitiveness of recycled materials would also be enhanced if all materials had to pay their externality costs.

Measuring materials value retention is an important complement to volume-based metrics. We believe this report also shows the importance of economic value-based approaches in addition to the traditional volume-based statistical metrics. The preserved value of recycled materials holds information about quality, price, and the actual replacement opportunities of virgin materials production by recycled materials. It also highlights new revenue opportunities for the private sector, and therefore is likely to stimulate innovation. Public statistics in Europe are already moving in this direction, with metrics shifting from what share of materials is being separated out for recycling, towards metrics showing the amount of recycled materials actually being produced and sold. Price and quality data would be excellent complements.

A number of differences were observed between the Swedish study published in 2018 and this report. First of all, the methodology used to calculate the value loss has since then been further developed and refined, especially through multiple discussions with various stakeholders on the results of the Swedish study. Additionally, many other data sources were used as European data was needed. This means our view of material value has become more refined, for example to not include reworking costs as a loss and ensuring the starting and end point for value only includes materials value and no product value.

In general, the results have very similar implications with value losses being much higher than official recycling rates indicate, but we can also observe a number of differences as well:

- While the percentage value losses seem to be higher in the Swedish report vs. the European report (70% vs 51%), this is mostly due to differences in the methodology described above. If we would redo the analysis for Sweden using our refined methodology the reverse would likely be true. In general, we see that Sweden is further ahead than Europe in average when it comes to a well-developed recycling infrastructure. For example, Europe has a significantly higher landfill rate than Sweden, which has already today almost fully phased out landfilling. The EU is also much more fragmented, with different recycling processes, standards, etc. than the Swedish system. This is to be expected given the many member states in the EU
- A second key difference is that Europe has a much wider regulatory toolbox that can be used to impact value preservation. For example, the EU has the authority to decide on product design policies, standards, etc. which can have a significant impact.

- Finally, it is on the European level that work needs to be done to integrate recycling systems to generate sufficient volumes of different material fractions and enabling better recycling. This was highlighted as a challenge for the Swedish system in isolation in the Swedish report, but has been further highlighted as a key priority for Europe.

Publication list

Publications from the project have not yet been published.

Project communication

The project will be presented on a number of occasions, including but not limited to

- An interview and related publication with RE:Source
- Presentation at the RE:Source-dagen 2020
- Digital launch in Q4 2020
- Dissemination at individual meetings with a number of policy makers and through seminars

References

The report will be published on the Material Economics' and RE:Source's websites. https://materialeconomics.com/publications/overview and https://resource-sip.se/projektdatabas/ .

Appendices

"Administrativ bilaga" and the main report are enclosed.