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Quantifying Impacts of Consumption Based Charge for Carbon Intensive Materials on Products

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Inclusion of consumption of carbon intensive materials in emissions trading - quantifying the impact across commodity groups

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April 21st, 2016

After the Paris Climate Agreement, it is anticipated that carbon prices will differ across regions for some time. If countries use free allowance allocation as carbon leakage protection, only a fraction of carbon prices are passed through to consumers particularly by carbon intensive materials producers. Adding a consumption charge based on benchmarks applied to the material content can reinstate the carbon price signal. The paper investigates the implications of such a consumption charge for industry and consumers based on material flow analysis and material flow cost accounting. The material-related carbon liabilities for production, import, export, and consumption are estimated for 4000 commodity groups that contain one or more of the five bulk materials steel, aluminium, plastics, paper, and cement. Assuming an underlying carbon price of 30 Euros per ton of CO2, the total charge to European final consumers is estimated to be about 17 billion EUR. The total charges levied on imports and those waived for exports are each of similar size and roughly amount to half of the total charge to European final consumers. To reduce administrative efforts, the charge is not levied on imported products for which the value of the consumption charge compared to product price falls below a threshold. Thus administrative efforts for 77 to 83% of imports could be avoided while still 85% to 90% of import-related carbon liabilities are included.

Keywords: Material flow analysis, Material flow cost accounting, Carbon Pricing, Inclusion of Consumption, EU Emissions Trading System,

JEL classifications: F18 - Trade and Environment, H23 - Externalities; Redistributive Effects; Environmental Taxes and Subsidies, Q56 - Environment and Development; Environment and Trade; Sustainability; Environmental Accounting

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1. Introduction

In Emission Trading Systems allowances are allocated for free to producers of carbon intensive materials like steel, aluminium, paper, plastics, and cement. This free allocation addresses concerns that additional costs for carbon emissions could result in relocation of production or investment decisions towards regions with lower carbon prices, so called *carbon leakage* (European Commission, 2016). The allocation of the allowances is based on benchmarks so as to preserve incentives for efficiency improvements of primary production. To ensure leakage protection and limit surplus allocation, the allocation is linked to activity level requirements and production volumes. Together with the convergence of prices through international trade this reduces the share of the carbon cost that is passed through to material prices and reduces the economic incentives for more efficient usage of these materials and material substitution. As final consumers do not pay for incremental costs, also the business case for the development of technologies for material production at incremental costs but with lower carbon emissions is reduced.

A *consumption-based charge for emissions intensive materials* can re-establish price signals for more climate-efficient material use in the manufacturing sectors and for end users (Neuhoff et al., 2016). The administrative burden of its implementation can, if designed in the right way, be moderate and does not provide disincentives for using recycled material or material with lower carbon footprint.

The administration cost is limited by focusing on carbon intensive materials with the biggest emission share. Complexity of tracing and monitoring is further reduced by using only one emissions benchmark for each material, irrespective of the production process. This also ensures compatibility with the rules of consumption charges. The benchmark for each material should thus reflect the carbon intensity of the marginal unit of production to serve final demand. With such a uniform approach, an appropriate incentive is provided encouraging the use of higher value materials, materials substitution, or efficient material use; any one potentially saving the emissions linked to this marginal unit. Incentives for efficient production of materials by installations covered by the ETS continue to be provided by the coverage of installations for material production and their electricity providers. Installations incur costs for emissions above benchmark level and can benefit from outperforming the benchmark.

We provide a quantitative analysis of the economic and administrative implications of adding such a consumption charge to an ETS system (‘*Inclusion of consumption’, IoC)*. Our analysis gives an estimate of the total volume of liabilities created, the significance of imports and exports, and the distribution of liabilities across commodity groups. We motivate our analysis with three research questions, listed below. The analysis focuses on the carbon intensive materials steel, aluminium, plastics, paper, and cement.

First, we investigate how big the liabilities are that are generated in the material production industries and during import, and how big are the liabilities acquitted by final consumers or exporters.

Second, we estimate the size of the liabilities relative to the product prices to get an idea of how large price signals could be and to understand the impacts on product prices. This estimate is the basis for the design of a *de-minimis* rule for product categories on which at the time of import no liability for the consumption charge needs to be created. The objective of the de-minimis rule is a limitation of administrative costs without creating undue advantages along the value chain. We ask what price changes are to be expected if a uniform system-wide carbon liability for materials was implemented and how the price changes are distributed across commodity groups.

Third, to keep the administrative burden low and the scheme effective, we assess how the liabilities are distributed across the commodity groups. This includes identifying which commodity groups are entirely made of steel, aluminium, plastics, paper, or cement: Their associated liabilities can be determined from their weight alone.

2. Methodology

We applied a combination of material flow analysis (MFA) and material flow cost accounting (MFCA) to estimate absolute and relative liabilities (Guenther, Jasch, Schmidt, Wagner, & Huisingh, 2012; Kytzia, Faist, & Baccini, 2004; Pauliuk, Majeau-Bettez, & Müller, 2015; A. Schmidt, Götze, & Sygulla, 2014; M. Schmidt, 2014).

As basis for our estimates we used the Europe-wide statistics on production, import, and export of manufactured goods (ProdCom), which is published by EuroStat annually for 4047 commodity groups in a refined NACEv2 classification (Eurostat, 2013). ProdCom statistics are reported in value units (EUR, layer 1) and volume units (kg for bulk materials, pieces for most manufactured goods, m^2 for textiles…, layer 2). The geographical scope is the EU28, the reference year we chose is 2012, the most recent year for which complete data were available.

Figure 1 shows the system definition. For each investigated commodity, we determined the apparent consumption with the market balance (equation 1):

$$Consumption = Production + Import - Export \qquad (1)$$

The system in Figure 1 was quantified for the flows of the different commodities for the reference year 2012 and with the EU28 as regional scope. Quantification was done for the monetary, physical, mass, and the five material layers for steel, aluminium, plastics, paper, and cement.

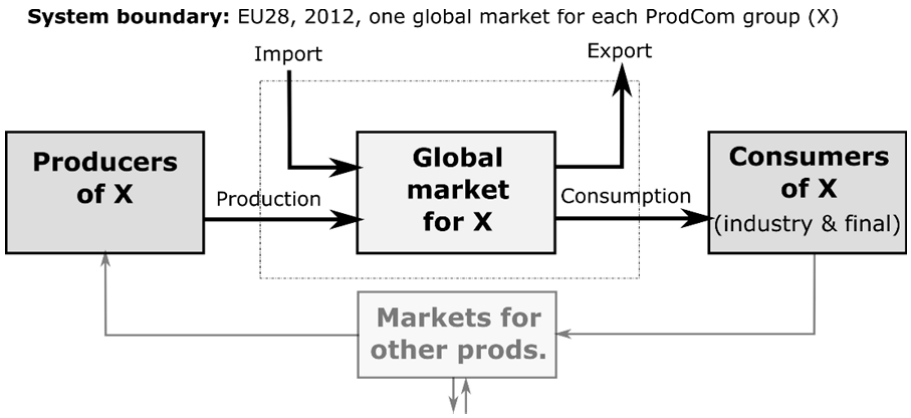

Figure 1. System definition. The drawing shows the global market for a selected commodity X. In total, 4047 such markets were considered.

We briefly describe the calculation scheme applied to the commodity markets and introduce the central parameters for the MFCA, which are explained in detail below. Figure 2 shows the scheme of calculations that was applied to the flows shown in Figure 1.

In a first step, we *filled data gaps* for the physical ProdCom account. Then, we converted all physical units to kg by multiplying the physical units with a conversion factor *kg/unit*. Then, we multiplied the mass flows of the 4047 categories with a group-by-group estimate of the *material content for the six materials* studied. We multiplied the so-obtained flows of embedded materials with the respective *carbon emissions benchmarks* for the six materials, and obtained the carbon charge embedded in the product flows by multiplying the embodied carbon emissions by the *carbon price*.

The five main results of the calculations are shown as grey boxes in Figure 2. We present the equations for each of them:

$$\begin{aligned}\text{Rel. embodied carbon} &= 1\text{ unit} \times \text{ kg/unit } \times \text{Material content} \times \text{Carbon intensity} \\ [kg_{CO_2}/kg] &= 1\,unit \cdot [kg/unit] \cdot [kg/kg] \cdot [kg_{CO_2}/kg]\end{aligned} \quad (1)$$

$$\begin{aligned}\text{Embodied carbon} &= \text{Volume} \times \text{ kg/unit } \times \text{Material content} \times \text{Carbon intensity} \\ [kg_{CO_2}] &= [unit] \cdot [kg/unit] \cdot [kg/kg] \cdot [kg_{CO_2}/kg]\end{aligned} \quad (2)$$

$$\begin{aligned}\text{Rel. embodied liability} &= 1\text{ unit} \times \text{ kg/unit } \times \text{Material content} \times \text{Carbon intensity} \times \text{Carbon price} \\ [€/kg] &= 1\,unit \cdot [kg/unit] \cdot [kg/kg] \cdot [kg_{CO_2}/kg] \cdot [€/kg_{CO_2}]\end{aligned} \quad (3)$$

$$\begin{aligned}\text{Embodied liability} &= \text{Volume} \times \text{ kg/unit } \times \text{Material content} \times \text{Carbon intensity} \times \text{Carbon price} \\ [€] &= [unit] \cdot [kg/unit] \cdot [kg/kg] \cdot [kg_{CO_2}/kg] \cdot [€/kg_{CO_2}]\end{aligned} \quad (4)$$

Finally, by dividing the total embedded liability by the monetary value of the flow, we obtained the ratio of liability to value, or – if the liability is paid – the relative price change

$$\begin{aligned}\text{Rel. price change} &= 100 \times \text{Total liability / Value} \\ [\%] &= 100 \cdot [€] / [€]\end{aligned} \quad (5)$$

For each of the five quantities, a sensitivity analysis was performed, and low, medium, and high estimates were calculated, depending on possible variations in material content. A ranking of the material content by group, the total liabilities by group, and the price changes by group helped us to identify which commodities are the most and the least affected by the emissions inclusion scheme, and our findings inform the discussion on threshold levels and economy-wide impacts. The quantitative results were obtained with a Python script.

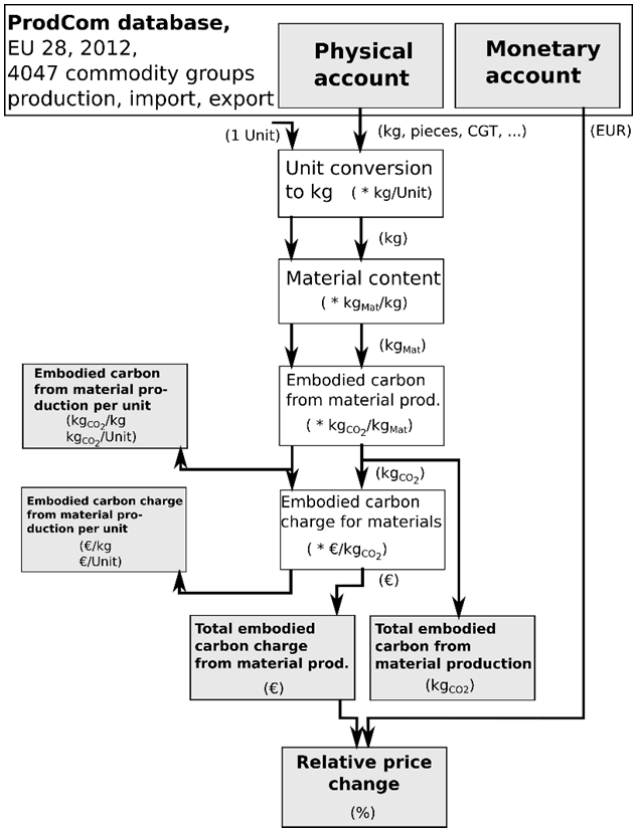

Figure 2: Calculation scheme for the estimation of liabilities and price changes for the 4047 ProdCom commodity groups.

3. Data collection and refinement

To estimate total liabilities we needed physical production and trade volumes at high commodity resolution. These data were obtained from the ProdCom database (Eurostat, 2013). To be compatible with the ProdCom categorization we also estimated the relative liabilities in the same classification. The ProdCom database is neither complete nor fully reliable, and we had to estimate missing physical data and correct the price estimates. Our treatment of the ProdCom raw data is documented here.

Physical and monetary production accounts

Monetary production and trade accounts are usually the ones with the best coverage, and we used these data as our reference. These data were not corrected and no check for completeness was performed. Physical data were often incomplete, however, and we estimated some of the missing data. First, we aggregated both monetary and physical flows to the 4-digit NACEv2 classification, which includes 240 commodity groups at the 4 digit level. For commodity groups with nonzero monetary flows but where no physical production account was present, we used the monetary production figure multiplied with the kg/EUR intensity of the corresponding 4-digit aggregation of the ProdCom database to estimate a proxy production mass flow. For some groups, no export and import-related physical data are present, and we then use the 4-digit aggregation of the trade data to determine a proxy in the same way as described above. In cases where there were no physical trade data in the 4-digit aggregation, we take the 4-digit production account as proxy to estimate the kg/EUR ratio for this aggregated group. With this method a mass flow account could be estimated for about 25% of the 4047 groups. For some groups, however, no physical data were present at all, and these groups (Table 1) were excluded from our analysis.

Table 1. List of 4-digit ProdCom groups where no physical data were available and that were therefore excluded from our analysis.

NACE v2 Code	Name	Potentially relevant for IoC
1330	Dying and printing services	No (Service)
1420	Articles of fur skins	No
1812	**Printed newspapers, books, maps, etc.**	**Yes**
1814-1820	Printing and reproduction services	No (Service)
2120	Medicaments and Vaccines	No
2550	**Die-forged, drop-forged, and extruded metal parts**	**Yes**
2561	Metallic coating and painting services	No (Service)
2562	**Turned metal parts**	**Yes**
2999	**Flashlights, image and cinematic projectors etc.**	**Yes**
3212	Goldsmiths' wares, other articles of precious metals	No
3311-3320	Maintenance, repair, and installation services	No (Service)

With the monetary account remaining unrefined due to a lack of reference data, some groups for manufactured products showed unrealistically high relative liabilities for production flows, which were in some cases much higher than the relative liabilities for the pure bulk materials. For example, 'Weirs, sluices, lock-gates, landing stages, fixed docks and other maritime and waterway structures, of iron or steel, Structures and parts of structures of iron or steel, n.e.s.' (26601230) showed a relative liability of about 22%, whereas for finished steel, it is only about 8%. Another example is 'Artificial monofilament of <= 67 decitex […]' (25112355), for which a relative price change for production of about 18% was reported, whereas for plastics/polymers, it was only about 1.6 %. These reason for these large relative liabilities stems from unrealistically low original average prices per kg in the ProdCom Database and from uncertainties regarding the conversion from the physical units to kg.

The large relative liabilities did not result from all ProdCom accounts, which is a further indication for incomplete or erroneous data. For example, the calculated relative liabilities for the import and export accounts, (not the production account) of 'Artificial monofilament of <= 67 decitex […]' (20602400) was below 0.2%, which is more realistic since the relative liability of plastics is about 1.6% and the degree of fabrication of artificial monofilaments is higher than the one of plastics.

We considered those cases where the calculated relative liabilities are significantly higher than the values for the pure bulk materials as outliers, and assume that in reality, products from these groups would not experience such a large price increase under an implementation of the consumption based charge. Therefore in the Python script we performed the following refinement: For production, import, and export accounts, we checked whether the relative liability was larger than the sum of the relative liabilities of the constituting materials, weighted by their respective material content. If this was the case, we checked whether the group is a pure bulk material. If yes, we replaced the calculated value by the reference value for this bulk material, which are presented below. If not, we took the relative liability of the 4-digit aggregation as proxy.

Conversion of physical units into kg (kg/unit)

The production and trade volumes of most manufactured goods and all vehicles are not reported in kg, as required for the material content estimation, but in other physical units including pieces (for manufactured goods, electronic components, or vehicles), square metres (m^2, for textiles or glass), or compensated gross tonnage (CGT, for ships). All these units had to be converted into kg in order to determine the material embedded in the mass flows. There are no official or established data sets for the weight per unit for different commodity groups. Although the classification is very detailed, the physical inhomogeneity within a single group can be significant. Consider, for example, the group 'Bodies for lorries, vans, buses, coaches, tractors, dumpers and special purpose motor vehicles including completely equipped and incomplete bodies, vehicles for the transport of <=10 persons' (29201050). It is not possible to say what the exact mass of an item in this group is, not only because it contains the bodies of different types of vehicles (lorries, coaches, tractors), but mainly, because it not only contains completely equipped bodies, but also incomplete bodies. Moreover, the composition of this group will change depending on where and when it is measured. The import of this group to France in 2012 is likely to have a very different composition from the production flow for this group in Sweden in the same year. The kg/unit conversion factors that we compiled and estimated are therefore to be seen as guidance values only that shall give a rough indication of the mass flows produced and traded. This rough estimate is sufficient to give an overview of the magnitude of liabilities embedded in manufactured goods and the relative price changes that are to be expected. It cannot replace, however, the determination of the liability and the price change for a specific good at a specific point in the economy.

Material content for steel, Al, copper, plastics, paper, and cement, group by group

There are no official or established data sets for the material content of different commodity groups. Although the classification is very detailed, the physical inhomogeneity within a single group can be significant. Consider, for example, the group 'Motor vehicles with a petrol engine > 1500 cm^3' (29102230). Neither is it not possible to say what the exact mass of an item in this group is, nor can we specific the material content with high accuracy. The reason behind the first item is that the engine volume can take any reasonable value larger than 1500 cm^3 or the specific technology or degree of equipment of the vehicle is not specified. The reason behind the second item is that there is considerable freedom in the choice of materials. Next to steel, the vehicles could contain considerable amounts of aluminium, carbon fibre or other fibre-reinforced composites (Allwood et al., 2012; Modaresi, Pauliuk, Løvik, & Müller, 2014). We applied a so-called 'bottom-up' approach when determining the content of steel, aluminium, copper, plastics, paper, and cement of the 4047 commodity groups, and assessed the uncertainty of our estimates.

Many groups, including agricultural products or minerals, clearly do not contain any of the six materials within the scope. The material content of those groups was set to zero. Others, for example, steel or plastic bulk commodities, have a definite material content of close to 100%. The material content of those groups was set to values between 96% and 100% to take into account the content of possible alloy elements or other additives. For all other groups, including all manufactured products, our estimation of material content group by group relies on expert knowledge and previous experience in tracing steel, aluminium, and cement through the world economy using the SITC1 classification (Liu & Müller, 2013; Müller et al., 2013; Pauliuk, Wang, & Müller, 2013). Moreover, we could use the peer-reviewed published results of the STAF project for estimating the steel and aluminium content of manufactured goods (Graedel et al., 2004; Johnson, Schewel, & Graedel, 2006). The results of the previous studies were matched to the NACEv2 classification and then checked group-by-group and refined where necessary. Uncertainties were estimated and in the dataset. In general, uncertainty is lowest for product groups with very high content of a specific material (down to +/- 5 percentage points), and highest for manufactured products with only minute amounts of materials.

Carbon emissions benchmarks for steel, aluminium, plastics, paper, and cement

To estimate the embodied GHG emissions in the five materials, we constructed process chains for the production of each material, in which the material or its precursors accumulate embodied GHG emissions (Figure A1). To quantify the emissions in the process chain of the products we combined process inventory data from the Ecoinvent life cycle database (Ecoinvent Centre, 2014) with current process-specific EU-ETS benchmarks for direct emissions (European Commission, 2011) and electricity use (European Commission, 2012a, 2012b). The existence or non-existence of EU-ETS benchmarks defined the scope of the process chain. This combination of EU-ETS process benchmarks with a simple product system model gave us product-specific benchmarks for the carbon emissions embodied in the five materials. For each material a specific system for its primary production was drawn and all relevant EU-ETS benchmarks were included (Figure A1). The resulting product-

specific benchmarks are listed and explained below (in tons of CO_2-eq. per ton of material). For all electricity use a benchmark of 0.76 t CO_2 per MWh was used, which is the EU-ETS benchmark of electricity generation in West Central Europe, and which lies roughly in the middle of the spectrum of the carbon intensity of European power production (European Commission, 2012a, 2012b).

- **Steel: 1.78**: The process chain for steel contains the production of coke and iron ore sinter with their respective EU-ETS benchmarks, the blast furnace, which is also included (EU Directive, L130/19), and the basic oxygen furnace with subsequent casting and rolling, for which the EU-ETS specifies a benchmark for electricity use (2012/C 387/06, and EU Communication, C158/22). We assumed that all iron is supplied by pig iron from the blast furnace.
- **Aluminium: 12.82:** The process chain for aluminium production contains the production of refined aluminium oxide and the associated electricity generation, the production of the anodes for the alumina reduction process, and the electrolysis with process emissions (EU Directive, L130/20) and associated electricity generation (2012/C 387/06). Electricity-related emissions for the electrolysis contribute with about 10.8 tons to the total product benchmark.
- **Cement: 0.69:** For grey cement klinker a benchmark for the rotary kiln of 0.766 is given (EU Directive, L130/20). The clinker content of cement varies and the exact benchmark for cement is therefore subject to debate. We assumed a system-wide klinker content of cement of 90% according to ecoinvent, which gives a benchmark for cement of 0.69. Electricity-related emissions, for example in the klinker mill, are not included in the EU-ETS.
- **Paper: 0.40:** For paper production we included both the paper and the pulp mill. According to Ecoinvent about one ton of pulp is required per ton of paper. For pulp we took the average of the EU-ETS benchmarks for long and short fibre pulp (0.06 and 0.12) and for paper we took the average of the EU-ETS benchmarks for newsprint and fine paper (0.298 and 0.318, EU Directive, L130/24 + 25).
- **Plastics: 1.5**. Polyvinyl chloride (PVC) is the only plastic for which the EU-ETS covers the polymerization process. A process chain for PVC was constructed using stoichiometric data on the vinyl chloride monomer content of PVC (100%) and the chlorine content of vinyl chloride (57%). Electricity-related emissions for chlorine production as well as direct emissions from the monomer production and the polymerization steps were included as well (EU Directive, L130/28). The product-related benchmark was found to be 1.50, and the main contributor is the chorine production step with ca. 70%. No analogue calculation for the other major plastics, including polyethylene (PE), polypropylene (PP), and polystyrene (PS) could be performed since the polymerization of these plastics is apparently not directly reflected in EU-ETS benchmarks. A comparison of the cradle-to-gate CO_2 emissions of the four plastics from Ecoinvent data showed that PVC (with 2.3 kg CO_2 per kg PVC) is in the middle of the spectrum of CO_2 intensities (1.5 kg CO_2 per kg PE, 1.7 kg CO_2 per kg PP, and 2.7 kg CO_2 per kg PS). We therefore used the PVC product benchmark as proxy for plastics, acknowledging that

this assumption needs to be refined in the future and that actual plastics-related embodied emissions that are within the scope of the EU-ETS might be lower than the benchmark used in this work.

The resulting product-related benchmarks comprising the relevant production steps are listed in Table 2.

Table 2. Emissions benchmarks used for determining the volume of liabilities incurred and acquitted.

Material	Emissions benchmark for primary production (kg CO_2/kg)	Reference	Liability for 100% material content (EUR/ton)
Steel	1.78	EU-ETS, ecoinvent	53
Aluminium	12.82	EU-ETS, ecoinvent	385
Plastics	1.50	EU-ETS, ecoinvent	45
Paper	0.40	EU-ETS, ecoinvent	12
Cement	0.69	EU-ETS, ecoinvent	21
Carbon price (Euro/kg of CO_2)	0.03	Assumption	

The carbon price was assumed to be at 30 €/ton CO_2, or 3 Cent/kg CO_2, which is a hypothetical but possible price for the next decades, when deep decarbonisation may take place.

With a given carbon benchmark for a material, one can calculate the maximum absolute price change due to the carbon liabilities for materials for a ton of product, which would occur if the product consisted to 100% of the given material (equ. 7).

$$\text{Max. price change / kg} = \text{Carbon footprint / kg} * \text{carbonprice / kg} \quad (6)$$

Results for the maximum absolute price change (or the liabilities for pure materials) are shown in the rightmost column of Table 2. With the given emissions benchmarks and carbon price, they range from 12 Euro/ton for paper to 385 Euro/ton for aluminium.

Commodity prices

To convert the carbon footprints per monetary unit of output into emissions benchmarks per mass (t/t), we divided the monetary benchmarks by the average price of supplying one ton of material. We used average commodity prices for the reference year 2007, which were obtained from a number of price index databases (Table 3). The reference year 2007 was chosen for compatibility reasons, as we also used the multi-regional input output model EXIOBASE for the analysis of the consumption based charge, and these data have 2007 as their reference year.

Table 3. Average commodity prices and references.

Material	Average price, 2007, MEUR/ton	Reference
Steel	0.000475	http://www.indexmundi.com/commodities/?commodity=cold-rolled-steel&months=300&currency=eur
Aluminium	0.001900	http://www.indexmundi.com/commodities/?commodity=aluminum&months=300&currency=eur
Plastics	0.000825	http://www.plastemart.com/lme_prices.asp?pricedate=2/10/2007
Paper	0.000800	Metsä Board's 1Q 2014 interim report presentation
Cement	0.000075	http://minerals.usgs.gov/minerals/pubs/commodity/cement/myb1-2007-cemen.pdf

Total production volumes

Table 4 shows the total production volumes for the six materials studied. These values were used to estimate the total liabilities generated during production.

Table 4. Production volumes of the six materials studied, EU28, 2012, in Mt.

Material	Total production, EU28, 2012, Mt	Reference
Steel	160	WorldSteel: Steel Statistical Yearbook, 2015
Aluminium	3.6	http://www.world-aluminium.org/statistics/
Plastics	57	http://www.plasticseurope.org/documents/document/20150227150049-final_plastics_the_facts_2014_2015_260215.pdf
Paper	100	http://www.cepi.org/system/files/public/documents/publications/statistics/2015/Key%20Statistics%202014%20FINAL.pdf
Cement	170	http://www.cembureau.be/sites/default/files/Cement%20production%20in%20CB%20and%20EU28.pdf

4. Results and discussion

A systems perspective on commodity flows under Inclusion of consumption

A consumption charge is applied to all goods sold to domestic consumers, irrespective of location of production or type of production process. Thus it also applies to imported goods so that final consumers see the same price signal for both imported and domestically produced goods. On the other hand, there should be no charge imposed on exported goods. These requirements lead to a scheme of liability creation and acquitting associated with material-intensive commodity flows (Figure 3). At the point of production, a liability is created for each material that falls under the scheme (case (1) in Figure 3). The liability is also created if the relevant materials are imported (case 6, 7, 8). The material-related liability is calculated as the product of the weight of material produced, the material-specific carbon benchmark, and the current carbon price. Companies can register for duty suspension agreement (DSA). In this case companies can acquire and handle materials with the charge without payments for the liability. They pass the liability along the value chain with the products sold.

Firms within the DSA can choose to pay the liabilities (case 4, 5) or pass it on to registered parties (case 2, 3). Firms will likely chose to directly pay the liability to avoid administrative

efforts if price changes are minute or products are not intended for exports. Hence domestic consumers will bear the consumption charge, irrespective of location or process of the production. This creates incentives for final consumers, but probably more relevant, intermediate consumers – namely manufacturers – to use materials more efficiently or substitute with less carbon intensive options.

To avoid charges on foreign consumers, the liability is acquitted if materials or products are exported (case (6)). However, if domestic firms that chose not to participate in DSA export products, then the liability can no longer be acquitted. To avoid incentives for fraud, financial compensation of previously incurred consumption charges is not envisaged (case (10)).

The central policy design choice that will determine the administrative efforts and incentives that result from the consumption charge is the definition of the de-minimis rule. For which product categories do importers not incur a liability and are consumers of imported products therefore exempt from the consumption charge?

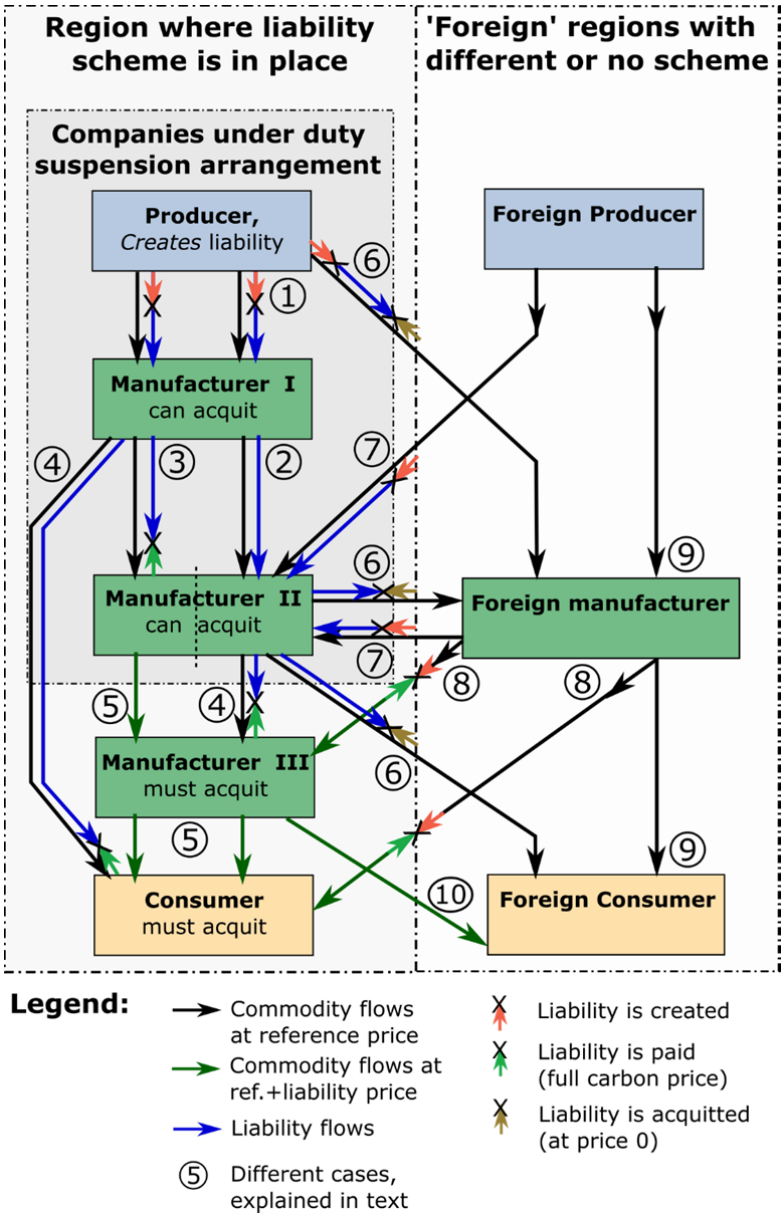

Figure 3: Scheme of commodity and liability flows under the inclusion of consumption. The different cases (1)-(10) are explained in the text above

Total liability linked to domestic production, consumption, imports and exports

In 2012, industry within the EU28 countries produced about 160 Mt of steel, 3.6 Mt of aluminium, 57 Mt of plastics, 100 Mt of paper, and 170 Mt of cement (Table 5). With the given EU-ETS emissions benchmarks and an assumed carbon price of 30 €/ton of CO_2, these production volumes correspond to liabilities of about 8500 MEUR for steel, 1400 MEUR for aluminium, 2500 MEUR for plastics, 1200 MEUR for paper, and 3600 MEUR for cement. The liabilities per ton of material differ substantially across materials, which is a result of differences in carbon intensity. For paper and cement the charge is 12 and 21 €/ton respectively, for plastics and steel 45 and 53 €/ton, and for aluminium about 385 €/ton.

Table 5: Material production, EU-ETS benchmarks, and total liabilities created, EU28, 2012. Data sources are listed in the methods section.

Material	Total production, EU28, 2012, Mt	EU-ETS benchmark t CO_2-eq/t	Liability per ton (EUR)	Total liability created within EU28 (MEUR)
Steel	160	1.780	53	8500
Aluminium	3.6	12.82	385	1400
Plastics	57	1.5	45	2500
Paper	100	0.4	12	1200
Cement	170	0.69	21	3600
Carbon price: EUR/t of CO_2	**30**		**Sum**	**17200**

The total volume of liabilities for the five materials in 2012 was about 17.000 MEUR. In addition to the liabilities for production, Table 6 shows our estimates of the liabilities created during import and acquitted during export. In import flows, aluminium- and steel-related liabilities each account for more than one third of the total. For export steel-related liabilities dominate with a share of more than 50%. The total trade-related liabilities roughly balance. Total liabilities (right column) were calculated as liabilities created plus import-related minus export-related liabilities. The first estimate of the magnitude of the total liabilities acquitted shows that total revenues of about 17.5 billion Euros would be generated with a carbon price of 30 €/ton and 2012 production levels. Of this amount, about 43% would stem from steel-related liabilities, followed by 20% for cement. Aluminium- and plastics-related liabilities would contribute with about 16% each, and paper about 6%.

Table 6: Total liabilities created and acquitted, EU28, 2012.

Material	Liability created within EU28 (MEUR)	Liability created during import (MEUR)	Liability acquitted during export (MEUR)	Liability paid by EU28 consumers (MEUR)
Steel	8500	3500	4450	7550
Aluminium	1400	3500	2200	2700
Plastics	2500	1700	1400	2800
Paper	1200	60	190	1050
Cement	3600	56	260	3400
Sum	**17200**	**8800**	**8500**	**17500**

With the given benchmarks and a carbon price of 30 €/t of CO_2, the material-related financial burden for final consumers within the EU would be in the range of 15-20 billion Euros.

The values presented in Tables 5 and 6 are only rough estimates, which depend on the actual material content of the traded commodities. Table 7 gives an impression of the possible variation of the trade-related liabilities as a result of variations in the material content of commodity groups. The sensitivity analysis showed that relative uncertainties of

±15% to ±25% are associated with variations in the content of steel, aluminium, and plastics of traded goods. This variation is a result of our ignorance of the exact material content of aggregated commodity groups such as motor vehicles, textile machines, or agricultural equipment. Paper and cement, which are mostly traded in pure form, exhibit no such variation.

In order to handle the variation of the material content in practice, one can imagine that a default material content is defined for each commodity group, which is then used to determine the default liability. If an importer can document a lower or different material composition, only then would the liabilities created be adjusted.

Table 7: Total liabilities incurred at point of import and acquitted at point of export, for low, medium, and high estimates of material content, respectively. Scope: EU28, production levels of 2012, carbon price 30 €/ton. All values in MEUR.

All values in MEUR	Import (incurred liabilities)			Export (acquitted liabilities)		
	low	medium	high	Low	medium	high
Steel	3041	3539	3734	3910	4459	4624
Aluminium	2669	3470	3958	1147	2196	2833
Plastics	1309	1684	2010	1126	1368	1529
Paper	59	59	59	186	187	187
Cement	56	57	57	257	261	265
Total	**7136**	**8808**	**9818**	**6625**	**8470**	**9439**

With the total amounts of liabilities known, we now turn our focus on how the liabilities per unit of product compare to commodity prices.

Prices changes for different commodity groups

With the average commodity prices, the EU-ETS benchmarks, and the carbon benchmark the relative liabilities for the five materials were calculated as the ratio between liability per ton and the material price per ton.

Table 8 summarizes our findings for commodity prices, the emissions benchmarks, the liabilities per ton, and the relative price changes that would result. Relative liabilities are lowest for paper (about 1.5%) and plastics (about 6%). Higher relative liabilities result for steel (11%), aluminium (20%), and cement (28%).

If the price of a commodity per kg is known, the emissions-related liability can be expressed in % of that price. If delivered to a final consumer or a company outside the duty suspension agreement (DSA), the liability would be paid and the price of the commodity would change accordingly.

Table 8. Relative liabilities for pure bulk commodities.

Material	Average price, 2007, MEUR/ton	EU-ETS benchmark t CO_2-eq/t	Liability per ton (EUR)	Relative liability / price change (%)
Steel	0.000475	1.780	53.4	11.2
Aluminium	0.001900	12.82	384.6	20.2
Plastics	0.0008250	1.5	45.0	5.5
Paper	0.000800	0.4	12.0	1.5
Cement	0.000075	0.69	20.7	27.6
Carbon price: EUR/t of CO_2	**30**			

Figure 4 shows typical relative liabilities (price changes) for selected commodities that contain only one material (Figure 4a) and manufactured goods that contain significant amounts of steel, aluminium, and plastics (Figure 4b). Relative price changes reach from about 28% for cement clinker[1] to about 8% for flat-rolled non-alloy steel, 17% for aluminium alloy plates, about 3% for ethylene polymers and approximately 1% for uncoated paper.

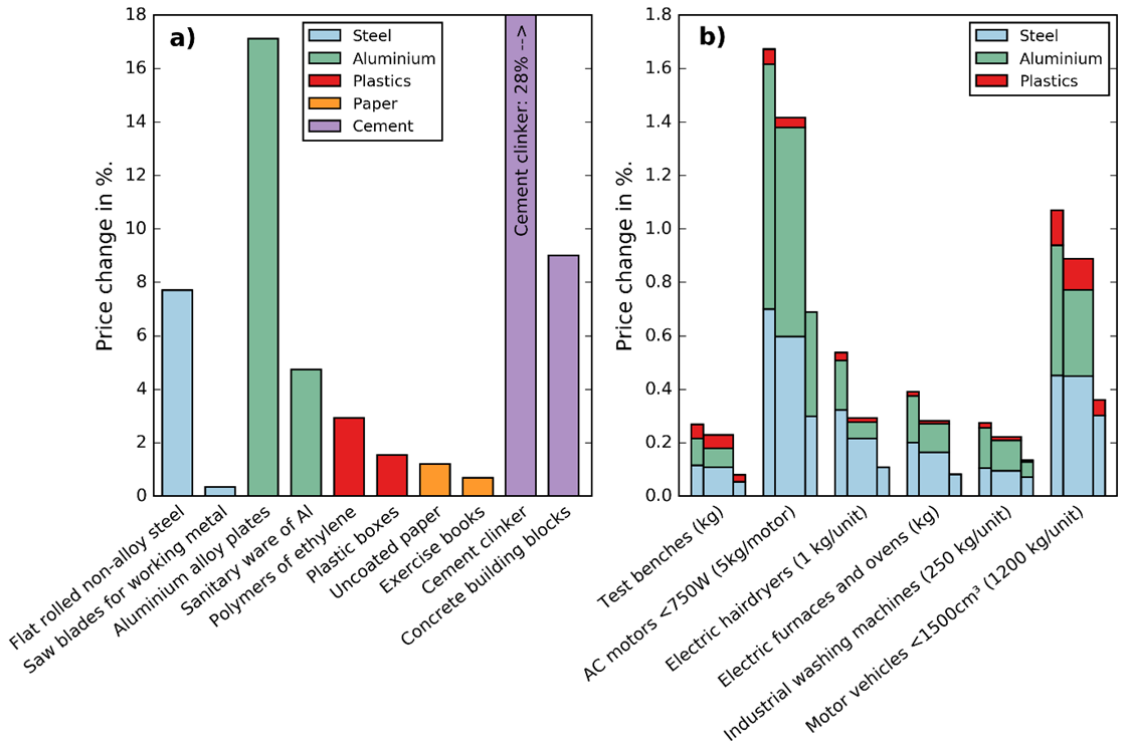

Figure 4. Typical relative liabilities (price changes) for selected commodities, production in the EU28 in 2012. In plot b) price changes are depicted for high (narrow column, left), medium (wide column, centre), and low (narrow column, right) values of material content.

[1] ProdCom reports a price of about 150 €/t, which is about twice the world market price of 75 €/t reported by the USGS and confirmed by experts. We disregarded the ProdCom data and took the USGS value as the reference.

Figure 4a also shows the relative liabilities (price changes) for manufactured goods that consist solely of one of the six materials being evaluated. These products show price changes between 9% for concrete building blocks (cement content estimated to be 20%), about 5% for sanitary ware of aluminium, about 0.3% of saw blades for working metal (steel content 95%), and roughly 1% for plastic boxes. The relative price changes of the manufactured products are consistently lower than those of the bulk materials, which is a consequence of the higher shares of value added in these products compared to the bulk materials.

Figure 4b shows the typical ranges of relative liabilities (price changes) for manufactured consumer products and industrial equipment. The price change for these types of goods typically lies between 0.1% and 1.5%. For most manufactured goods with significant liabilities, aluminium and steel are the largest contributors, followed by plastics. The sensitivity analysis shows that because of large possible variations in the material content of product groups, a direct consequence of their diversity, the resulting price changes form a range of possible values rather than specific fixed values.

To further illustrate the progression of liabilities along the value chain, we study the example of a typical European passenger vehicle of a weight of 1300 kg, a basic price of 10000 €, a steel content of 800 kg, an aluminium content of 100 kg, and a plastic content of 200 kg (Modaresi et al., 2014). We consider three stages of the value chain: raw material production where liabilities are created, component manufacture represented by gearbox and seat manufacturing, and the car manufacturing plant (Figure 5).

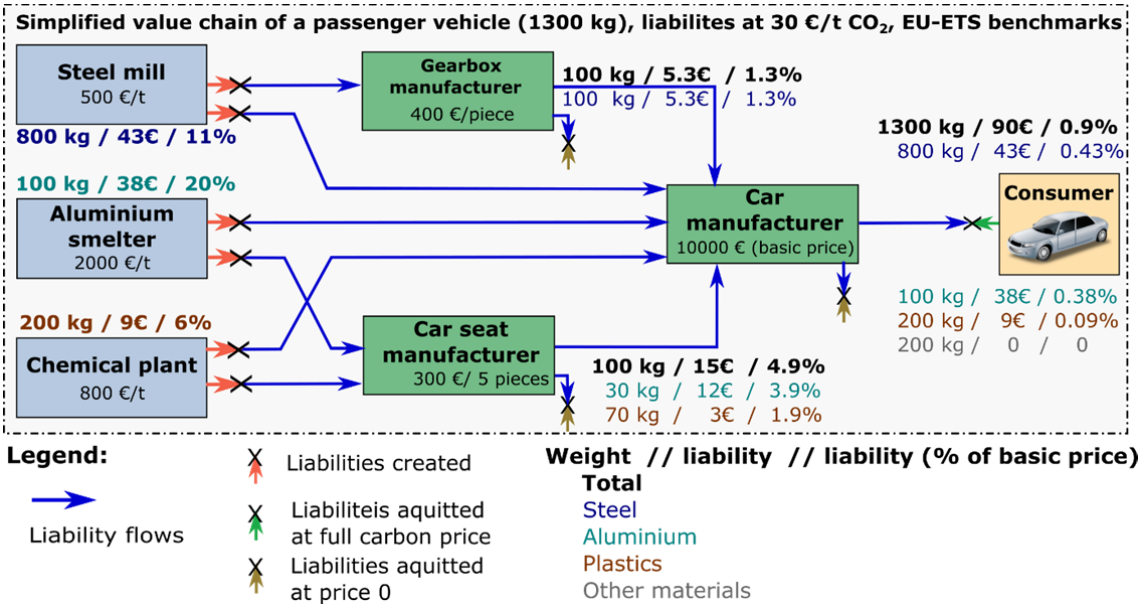

Figure 5. Simplified value chain of a passenger vehicle. Three materials (steel, aluminium, and plastics) and two components (gearbox and seats) are considered. The figure shows the material contained (in kg), the total liability (in €), and the liability as fraction of the basic price (in %) for the sum total (bold face), and for steel (dark blue), aluminium (light blue), and plastics (brown), respectively.

The relative liability decreases at every step in the value chain, as the share of cumulative valued added of the products' prices becomes larger. While finished steel has a relative liability of about 11%, the gearbox has one of about 1.3%, and in the car, steel-related liabilities account for only for 0.43% of the basic price. With current benchmarks and a carbon price of 30 €/t, each buyer of a car would have to pay for material-related liabilities of about 90 €, of which 43 € are associated with steel, 38 € with aluminium, and about 9 € with plastics. Because of the possible variations of the material composition of cars, these values are rough indicators only that show the order of magnitude of liabilities. The largest price signal is sent to the first users of finished materials, and these users often are also the ones who make the design choices; for example, the car seat manufacturer shown in Figure 5.

We now present the overview of expected commodity price changes for the entire EU28. Figure 6 shows a histogram plot of the number of ProdCom categories that experience a certain price change if sold to a consumer within the EU28. The EU ProdCom database contains data on production volumes, imports, and exports for 4047 commodity groups, both in in monetary units (EUR) and in physical units (kg or pieces) (Eurostat, 2013). ProdCom data can be used to estimate relative liabilities for only those groups where both physical and economic production data are reported.

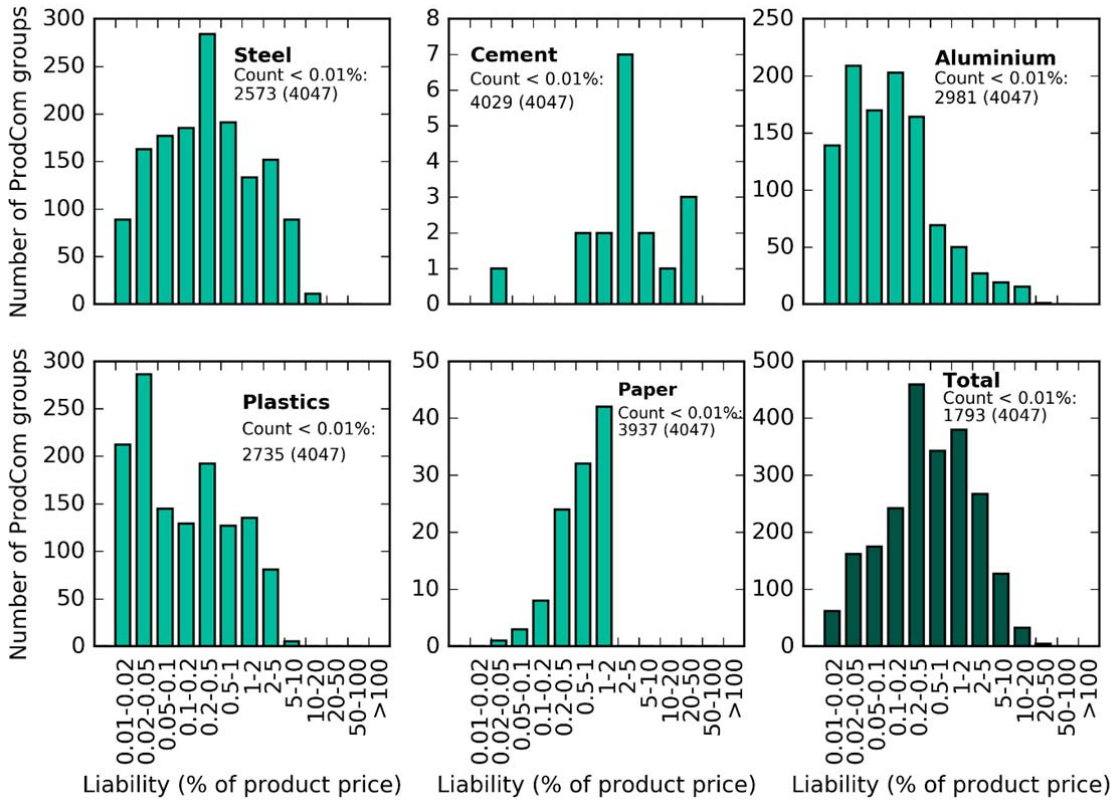

Figure 6. Histogram of the number of ProdCom groups with a certain relative liability (in %). Results are shown for the 2012 production flows within the EU28, five materials, and the sum total of the relative liabilities of the five materials.

This includes 3294 of 4047 groups for the production account. Out of the 4047 groups in the ProdCom database, 2573 groups for steel and 4029 groups for cement show a price change of 0 to 0.01%. The vast majority of the remaining groups for steel, aluminium, and plastics show price changes between 0.01 and 5%; these are groups where the materials were used in the manufacturing of products (metals and plastics). Cement and paper, which are often sold in pure form to final consumers (or concrete for cement), tend to carry higher relative liabilities.

The largest relative liabilities and associated price signals would occur for cement, with relative liabilities of up to 28%, followed by aluminium with up to 20%, steel with up to 11%, plastics with up to 6%, and paper with up to 2%. One can also say that cement is cheap compared to its embedded carbon liabilities, whereas plastics is already relatively expensive compared to its carbon intensity.

Table 9 shows the same information as displayed in Figure 6, in a histogram where the 4047 ProdCom groups are allocated into bins according to their relative liability (liability per kg in % of product price per kg). Results include total production, primary material production, import, and export flows and the relative liabilities associated with the five materials and the sum total, broken down in intervals from < 0.01% to 50%.

Table 9: The 4047 ProdCom groups sorted by liability per unit relative to price for the production flows of the EU28 in 2012.

Production	Steel, low	Steel, medium	Steel, high	Al, low	Al, medium	Al, high	Cement, low	Cement, medium	Cement, high	Total, low	Total, medium	Total, high
< 0.01%	2703	**2573**	2544	3818	**2981**	2906	4030	**4029**	4029	1897	**1793**	1780
0.01%-0.02%	82	**89**	75	25	**139**	91	0	**0**	0	108	**62**	39
0.02%-0.05%	187	**163**	153	45	**209**	190	1	**1**	0	196	**162**	132
0.05%-0.1%	154	**177**	174	34	**170**	173	0	**0**	1	233	**175**	156
0.1%-0.2%	193	**185**	192	28	**203**	188	0	**0**	0	275	**242**	223
0.2%-0.5%	250	**284**	310	30	**164**	233	0	**0**	0	420	**459**	441
0.5%-1%	144	**191**	191	15	**69**	120	2	**2**	1	293	**343**	377
1%-2%	104	**133**	150	8	**50**	59	3	**2**	1	270	**380**	422
2%-5%	131	**152**	154	13	**27**	44	6	**7**	7	210	**267**	290
5%-10%	87	**89**	93	15	**19**	26	2	**2**	3	113	**127**	145
10%-20%	12	**11**	11	15	**15**	16	0	**1**	2	28	**33**	38
20%-50%	0	**0**	0	1	**1**	1	3	**3**	3	4	**4**	4

The distribution in Table 9 gives a clear hint on that relatively few commodity groups include the bulk of the total liabilities, and Table 9 and Figure 6 show that relative liabilities are below 1% for more than 85% of all commodity groups.

Commodity groups with only one material – and with minute shares of materials

Table 10 shows the number of commodity groups whose material content lies above the four thresholds of 0, 0.1, 0.5, and 0.95, respectively. Results are given for the low, medium, and high estimate of material content, respectively.

The vast majority of the commodity groups with material content larger than 0.95 are the pure bulk material groups like 'Tubes and pipes, of non-circular cross-section, seamless, and hollow profiles, seamless, of steel' (24201400) or 'Polyvinyl chloride, not mixed with any other substances, in primary forms' (20163010). For aluminium, plastics, paper, and cement, the number of categories with pure materials (>0.95) is rather insensitive to the possible variations in material content. Steel represents an exception, as for the high material content estimate, 334 groups are included, which is 60 groups more than for the average estimate. The reason is that there are several groups of manufactured products, mostly machines, containing a very high average share of steel (around 0.8) and that can sometimes be made almost entirely out of steel. Examples include 'Machines for working wire (excluding draw-benches, thread rolling machines)' (28413450) or 'Centrifugal pumps with a discharge outlet diameter > 15 mm, multi-stage (including self-priming)' (28131460).

Table 10. Number of commodity groups in ProdCom in NACEv2 classification, whose material content exceeds 0, 0.1, 0.5, and 0.95 kg/kg, respectively. The total number of groups in the ProdCom NACEv2 classification is 4047. The table shows the counts for the lower (left), medium (middle, bold), and higher (right) estimates for material content.

	Total	Entries not 0	Entries > 0.1	Entries > 0.5	Entries > 0.95
Iron/steel		1699-**1832**-1832	1544-**1733**-1761	966-**1403**-1512	274-**274**-334
Al		297-**1387**-1387	71-**88**-360	35-**50**-50	26-**26**-32
Plastics	**4047**	1091-**1941**-1941	902-**1012**-1161	348-**400**-612	278-**278**-300
Paper		136-**136**-136	135-**136**-136	133-**133**-134	116-**116**-116
Cement		19-**20**-20	19-**19**-19	4-**4**-4	4-**4**-4

Table 10 also shows that less than half of the commodity groups have noteworthy concentrations of the five materials. If one would use a content of 10% as threshold for inclusion in the scheme, still, 1544-1761 commodity groups would have to be considered for steel, 902-1161 for plastics, 71-360 for aluminium, 135-136 for paper, and 19 for cement. Quite a large number of groups consists of more than 50% of a certain material, this affects 966-1512 groups for iron/steel, 35-50 for aluminium, 348-612 for plastics, about 134 for paper, and only 4 for cement.

Commodities with insignificant amount of the five materials covered by the consumption based charge mostly belong to one of the following groups: agricultural products (other than paper/pulp), chemicals (other than plastics), ceramics, nonferrous metals (other than aluminium), and services.

Commodity groups according to their contribution to total liability

Cement and aluminium lead the list of production-related liabilities, ranked by liabilities embedded for the EU28 in 2012. (See Table A1 in the Annex). Aluminium (unwrought, alloy bars, and rods) and steel (flat rolled) lead the list of import-related liabilities (Table A2 in the Annex). About 13 of the top fifty groups in the production table are finished steel commodities and about 10 groups are finished aluminium metal groups. About 15 out of 50 groups are manufactured products or parts thereof, led by 'weirs and lock-gates' (place 6, probably due to a mistake in the physical flow account), 'gear boxes and parts thereof' (place 8), and 'motor vehicles with petrol engines' (place 11).

More than 50% of the 4047 ProdCom commodity groups contribute with less than 100,000 EUR to the total production-related liabilities (Table 11). In contrast, the number of groups with production liabilities of 10 MEUR or more is limited to 252-298 for steel, 53-132 for aluminium, 131-175 for plastics, 30 for paper, and 12-13 for cement. Table 11 shows that there is at least one commodity group for each of the five materials that contains liabilities of 100 MEUR or more.

Table 11: The 4047 ProdCom groups sorted by amount of liability for the production flows inside the EU28 in 2012.

Production	Steel, low	Steel, medium	Steel, high	Al, low	Al, medium	Al, high	Cement, low	Cement, medium	Cement, high	Total, low	Total, medium	Total, high
< 0.1 MEUR	2926	**2798**	2761	3851	**3210**	3128	4031	**4030**	4030	2215	**2056**	2008
0.1-0.5 MEUR	304	**330**	329	63	**351**	303	1	**0**	0	478	**426**	390
0.5-1 MEUR	138	**153**	162	25	**110**	149	1	**1**	1	207	**237**	236
1-5 MEUR	324	**350**	353	41	**228**	265	2	**2**	2	486	**532**	559
5-10 MEUR	103	**133**	144	14	**39**	70	0	**2**	1	191	**241**	235
10-50 MEUR	162	**183**	196	26	**64**	79	3	**2**	2	306	**360**	410
50-100 MEUR	35	**45**	44	9	**17**	21	1	**2**	2	68	**88**	93
100-500 MEUR	48	**48**	51	11	**21**	24	5	**5**	6	79	**86**	92
500-1000 MEUR	6	**6**	6	5	**5**	6	1	**1**	1	12	**16**	18
> 1000 MEUR	1	**1**	1	2	**2**	2	2	**2**	2	5	**5**	6

We further explore the distribution of liabilities across commodity groups in Table 12, where we show the minimum number of ProdCom categories that need to be included in the scheme to cover the indicated percentage of total liability. These results were obtained by ranking all commodity groups by contained total liability for the five materials. Table 12 also shows the value of imports or exports that relates to the trade in these product categories.

Table 12. Result of a ranking of all 4047 commodity groups by the amount of liabilities contained. The table shows the minimum number of categories that cover a certain percentage of all liabilities contained in imported and exported commodities, and the value of trade in these product categories.

Percentage of liability	Import		Export	
	Number of ProdCom categories included	Value of imports included, billion EUR	Number of ProdCom categories included	Value of exports included, billion EUR
5	1	4	2	77
10	2	8	4	81
15	2	8	6	83
20	3	11	10	88
25	5	14	15	107
30	9	17	22	128
35	15	32	29	137
40	23	51	38	150
45	32	68	48	165
50	**45**	**84**	**61**	**197**
55	62	98	78	227
60	83	125	100	249
65	110	141	129	275
70	148	170	165	305
75	198	200	214	336
80	266	286	280	377
85	364	337	371	424
90	**517**	**401**	**515**	**524**
95	798	517	771	654
100	**2251**	**750**	**2251**	**999**

If the commodity groups with the largest associated liabilities were monitored first, 90% coverage of trade-related liabilities could be achieved by including between 500 and 550 groups. Since trade volumes can change quickly and other groups contain higher relative liabilities, the scheme should potentially not only include those groups with historically high total liabilities but also those groups with high relative liabilities, which we identify in the last step of our analysis.

Combined analysis

Finally, we summarize our findings on the distribution of liabilities across commodity groups and the possible relative price changes by showing how liabilities are distributed across imported (Figure 7) and exported (Figure 8) commodities.

All import and export flows are ranked according to their relative liability (in %) and then this relative liability was plotted over the cumulative imports and exports. This means that the area of each bar represents the total liabilities embedded in the trade of this particular group, broken down into the five materials studied.

In contrast to table 12, in Figures 7 and 8 also product groups are identified with a low overall size, but a significant liability measured as share of the product price.

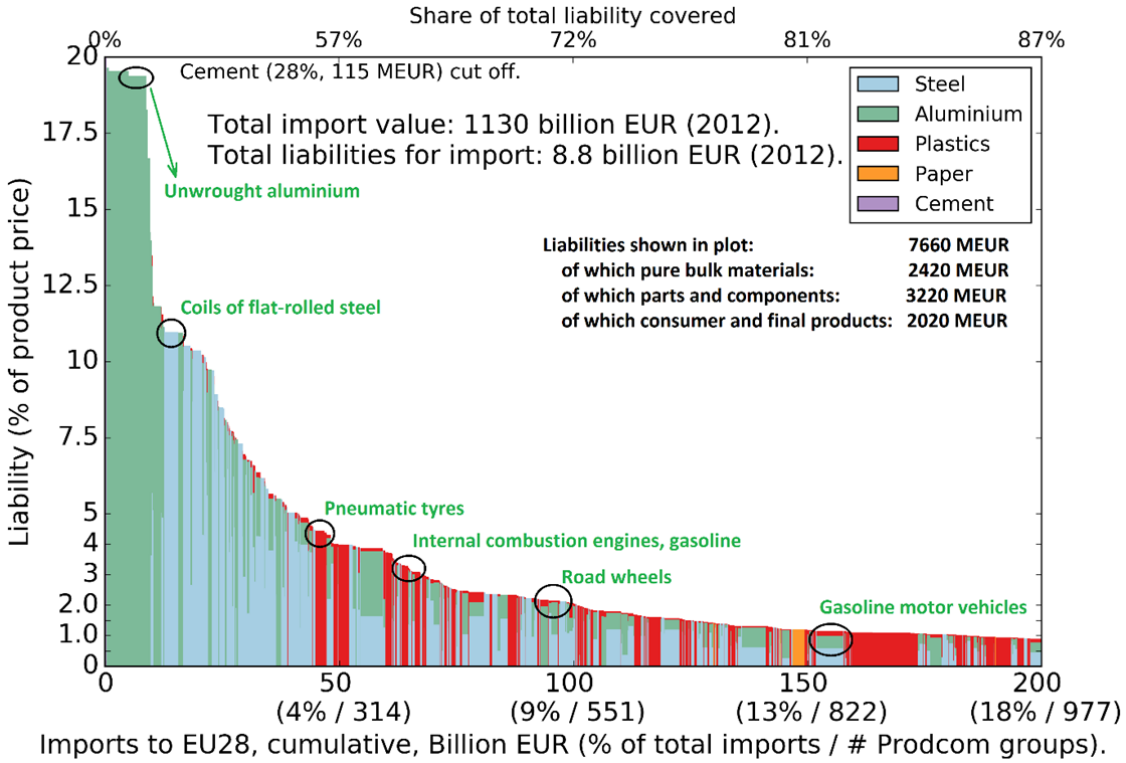

Figure 7. Imports into the EU28 in 2012, cumulative, sorted by relative liability or price change (%).

Steel (blue) and aluminium (green), as well as products consisting mostly thereof dominate the liabilities created during import and waved during export. Trade of plastics (red), and paper (orange) also plays a role as there are some commodity groups that consist entirely of these two materials.

Pure bulk material groups of cement, steel, and aluminium, with relative liabilities of more than 5%, are mostly found on the left side of the curves; parts and components, such as road wheels or pneumatic tyres, are found in the middle with relative liabilities between 1 and 2 %; and manufactured goods with a relative liabilities of below 1% can be found on the right side.

The liability as share of product price exceeds 1% in about 950 commodity groups that account together for 17% of imports. These 17% of imports comprise 86% of all import-related liabilities. To increase the coverage to 90% of all trade-related liabilities in imports, product categories with a liability share of product price exceeding 0,73% need to be included, accounting for about 1100 ProdCom commodity groups and 21% of total imports by value.

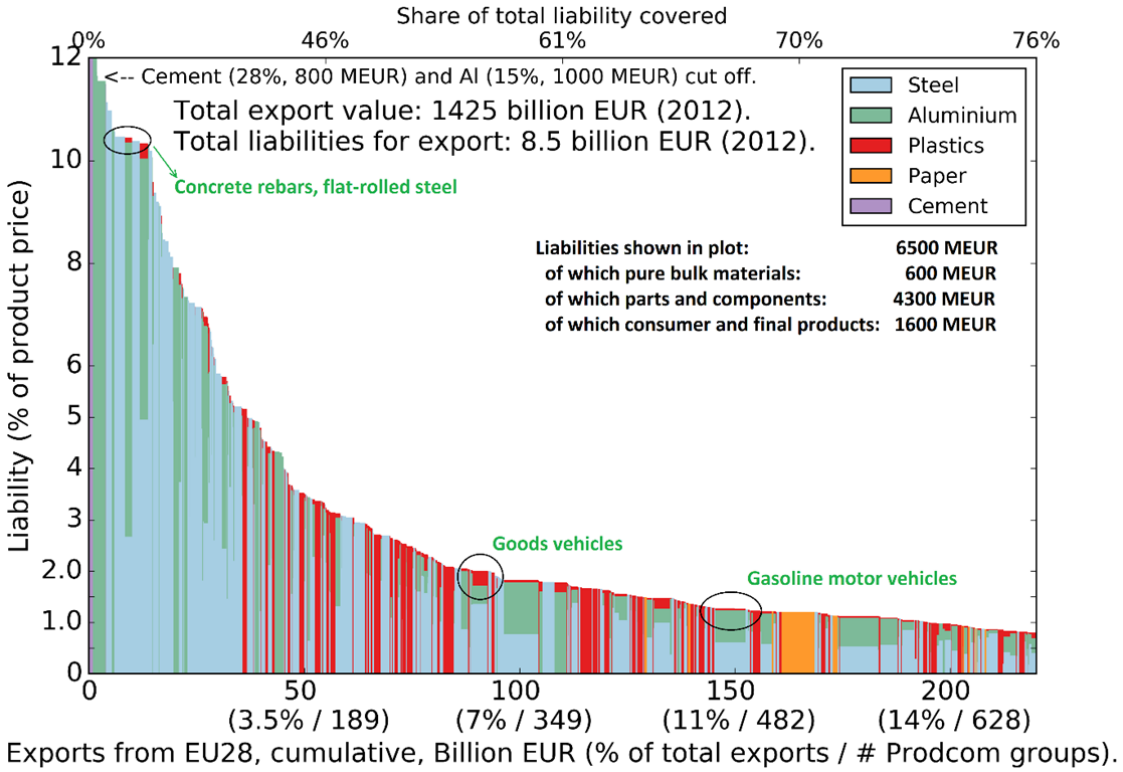

Figure 8. Exports from the EU28 in 2012, cumulative, sorted by relative liability (price change) (%).

For practical implementation it might be warranted to consider all import categories exceeding a product price increase threshold of, for example, 1%, and then to then add additional product categories exceeding the 0,73% threshold where this would be necessary to avoid incentives for shifting final assembly of products to foreign territory. Thus the total number of considered product categories may be between 900 and 1100 comprising 17% to 21% of total imports. If initially coverage is limited to a sub-set of the materials that comprise the bulk of emissions and thus also mitigation potential, for example steel, aluminium and cement, then the number and share of product categories considered could be reduced.

5. Conclusion

We studied how liabilities from including the consumption of five materials (steel, aluminium, plastics, paper, and cement) in the EU-ETS are distributed across the 4047 commodity groups, and how commodity prices would change if liabilities were to be paid by final consumers.

With current EU-ETS benchmarks and a carbon price of 30 €/ton of CO_2, the total liability attributed to European consumers would be in the order of 17 billion € per year. Import- and export-related liabilities roughly balance, they account each for about 8.5 billion € per

year or roughly 50% of the total amount of liabilities acquitted by consumers within the EU28.

For the manufactured goods, liabilities and price changes were computed using physical ProdCom data, which are often incomplete and which had to be converted from per unit to per kg. If price changes were higher than prices changes for pure bulk material commodities, these results were considered outliers and they were replaced by the average price change for the aggregated commodity group on the 4-digit NACE level.

We found that liabilities are unequally distributed across commodity groups. Expressed in terms of commodity prices, liabilities for finished steel, finished aluminium, and cement product groups are between 11% and 28%. Relative liabilities for most manufactured goods are below 2%.

For domestically manufactured products, the liability is traced from the inputs of the basic materials and will thus be accurately reflected. For imported products, a default material content could be set for each group, and liabilities would be determined using that content. Lower liabilities would only be created if the material content is reported.

A de-minimis rule reduces administrative requirements by defining product categories for which at the time of import no liability for the consumption charge is incurred. This should both retain effective incentives and avoid undue discrimination between domestic and foreign produced materials. For the five materials considered we find that coverage of 85%-90% of the liability for the consumption charge relating to imports can be ensured if 900-1100 ProdCom product categories are covered comprising 17%-21% of imports by value. If, during an initial stage of the scheme, coverage was limited to a sub-set of the materials that comprise the bulk of emissions and thus also mitigation potential, for example steel, aluminium and cement, then the number and share of product categories considered could be reduced.

Roughly 50% of the groups in the monitored fraction are pure bulk material groups, which contain 95% or more of one material and whose liabilities can be determined directly from the commodity weight. For the remaining groups material content exhibits significant variations, especially within the groups for manufactured products. The uncertainty of material content for manufactured goods is a result of the inhomogeneity within the already highly disaggregated product categories.

Overall we find that availability and quality of data is well suited to support a policy design that allocates responsibility for carbon to consumers based on benchmarks. Anticipation of this charge allocated to carbon intensive material choices also creates incentives along the value chain. Responsibility for emissions from materials production exceeding the benchmark needs to remains with producers that therefore need to remain covered in the emission trading systems.

Annex

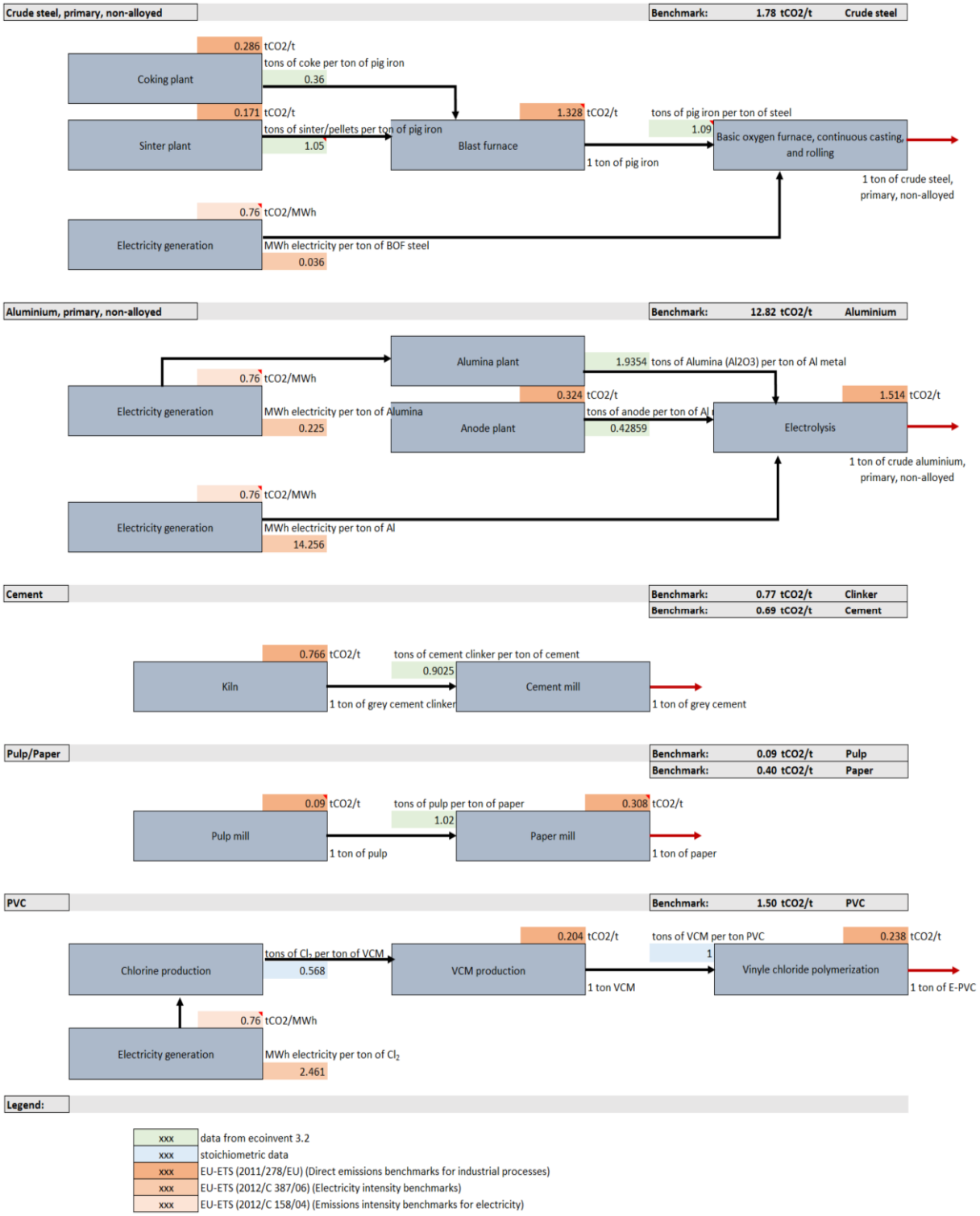

Figure A1. System definition for the derivation of product-specific emissions benchmarks for the five materials studied. The process chains were built using data from ecoinvent (Ecoinvent Centre, 2014) and stoichiometric information. The EU-ETS emissions benchmarks for processes define the scope of the process chains and the emissions multipliers.

Table A1. Top 50 commodity groups, ranked by liabilities created at the **moment of production**, for the five materials. Unit: MEUR. Scope: EU28, 2012. Column 2 shows the ProdCom code. **Note:** This table comprises consecutive steps of the value chain and therefore contains double-counted liabilities.

Liability, production, MEUR, EU28, 2012		Steel	Al	Plast.	Paper	Cement	TOTAL
Portland cement	23511210	0	0	0	0	2986	**2986**
Ready-mixed concrete	23631000	0	0	0	0	2119	**2119**
Aluminium alloy plates	24422450	0	1295	0	0	0	**1295**
Flat-rolled products of iron	24103110	1268	0	0	0	0	**1268**
Unwrought aluminium alloys	24421155	0	1038	0	0	0	**1038**
Maritime and waterway structs.	25112355	915	0	0	0	0	**915**
Aluminium alloy bars, rods	24422250	0	910	0	0	0	**910**
Gear boxes and their parts	29323033	430	442	26	0	0	**898**
Hot dipped metal coated sheet	24105130	821	0	0	0	0	**821**
Hot rolled concrete reinforcing	24106210	814	0	0	0	0	**814**
Motor vehicles with a petrol eng.	29102230	367	264	95	0	0	**726**
Ingots, other primary forms	24102IZ0	711	0	0	0	0	**711**
Aluminium plates, sheets	24422430	0	668	0	0	0	**668**
Motor vehicles with a diesel	29102330	328	236	85	0	0	**649**
Aluminium structure and parts	25112370	0	647	0	0	0	**647**
Unwrought aluminium alloys	24421153	0	639	0	0	0	**639**
Other hydraulic cements	23511290	0	0	0	0	629	**629**
Aluminium doors	25121050	0	597	0	0	0	**597**
Other parts and accessories	29323090	281	289	17	0	0	**586**
Uncoated cold rolled sheet	24104IZ0	547	0	0	0	0	**547**
Uncoated cold rolled sheet	24104110	541	0	0	0	0	**541**
"Instruments and appliances	32501370	254	110	128	0	0	**492**
Other wire rod	24106190	478	0	0	0	0	**478**
"Casks, drums, cans, boxes	25921240	82	373	0	0	0	**455**
Connections and contacts	27331370	180	235	11	0	0	**426**
Parts and of vehicle bodies	29322090	198	204	12	0	0	**414**
Flat-rolled products, of iron	24103150	404	0	0	0	0	**404**
Aluminium foil of a thickness	24422500	0	395	0	0	0	**395**
Polypropylene, in primary forms	20165130	0	0	388	0	0	**388**
Flat semi-finished products	24102110	368	0	0	0	0	**368**
Other ingots, primary forms	24102122	357	0	0	0	0	**357**
Flat-rolled products	24103510	335	0	0	0	0	**335**
Base metal closures, stoppers	25921370	60	275	0	0	0	**335**
Light metal castings for vehicles	24531010	0	335	0	0	0	**335**
Prefabricated structural comp.	23611200	0	0	0	0	332	**332**
Plastic carboys, bottles, flasks	22221450	0	0	330	0	0	**330**
Goods vehicles with a diesel	29104110	214	58	45	0	0	**316**
Vehicles with spark-ignition eng.	29102100	158	114	41	0	0	**313**
Iron or steel doors, thresholds	25121030	308	0	0	0	0	**308**
Ingots, other primary forms	24102121	307	0	0	0	0	**307**
Hot rolled flat products in coils	24103IZ0	306	0	0	0	0	**306**
Prefabricated buildings, of iron	25111030	286	0	0	0	0	**286**
Articles for the conveyance	22221950	0	0	277	0	0	**277**
Other electric conductors	27321380	0	240	28	0	0	**269**
Suspension systems and parts	29323050	127	130	8	0	0	**265**
Polyethylene	20161050	0	0	263	0	0	**263**
Sacks and bags of polymers	22221100	0	0	262	0	0	**262**
Ingots, other primary forms	24102IZ0	259	0	0	0	0	**259**
Unwrought non-alloy aluminium	24421130	0	259	0	0	0	**259**
Other structures of steel	25112350	257	0	0	0	0	**257**

Table A2. Top 50 commodity groups, ranked by liabilities created at the moment of import, for six materials. Unit: MEUR. Scope: EU28, 2012. Column 2 shows the ProdCom code.

Liability, import, MEUR, EU28, 2012		Steel	Al	Plast.	Paper	Cement	TOTAL
Unwrought aluminium alloys	24421153	0	824	0	0	0	**824**
Unwrought non-alloy aluminium	24421130	0	748	0	0	0	**748**
Flat semi-finished products	24102110	315	0	0	0	0	**315**
Flat-rolled products of iron	24103110	187	0	0	0	0	**187**
Aluminium alloy plates, sheets	24422450	0	181	0	0	0	**181**
Aluminium alloy bars, rods	24422250	0	110	0	0	0	**110**
Pig iron and spiegeleisen	24101100	98	0	0	0	0	**98**
Aluminium plates, sheets	24422430	0	95	0	0	0	**95**
Non-alloy aluminium wire	24422330	0	92	0	0	0	**92**
T-shirts, singlets and vests	14143000	0	0	85	0	0	**85**
Flat-rolled products, of iron	24103150	80	0	0	0	0	**80**
Goods vehicles with diesel eng.	29104110	54	14	11	0	0	**79**
Aluminium foil	24422500	0	75	0	0	0	**75**
Ferro-chromium	24101260	74	0	0	0	0	**74**
Hot dipped metal coated sheet	24105130	71	0	0	0	0	**71**
Vehicles with spark-ignition eng.	29102100	33	24	9	0	0	**66**
Uncoated cold rolled sheet	241041Z0	60	0	0	0	0	**60**
Articles of aluminium, n.e.c.	25992955	0	59	0	0	0	**59**
Motor vehicles with diesel eng.	29102330	29	21	8	0	0	**58**
Ferrous products	24101300	57	0	0	0	0	**57**
Ingots, other primary forms	241021Z0	52	0	0	0	0	**52**
Static converters	27115070	22	28	1	0	0	**51**
Parts for machines	27116100	20	27	1	0	0	**48**
Polyethylene	20161050	0	0	47	0	0	**47**
Other transformers, n.e.c.	27114240	19	25	1	0	0	**46**
Organic coated sheet	24105140	44	0	0	0	0	**44**
Motor vehicles with petrol eng.	29102230	22	16	6	0	0	**44**
Unwrought aluminium alloys	24421155	0	44	0	0	0	**44**
Linear polyethylene	20161035	0	0	44	0	0	**44**
Parts suitable for machines	28114200	21	22	1	0	0	**44**
Agrarian tyres; other	22111400	0	0	44	0	0	**44**
New pneumatic rubber tyres	22111100	0	0	43	0	0	**43**
Synthetic rubber	20171090	0	0	39	0	0	**39**
Parts of machinery of HS 84.25	28221930	31	6	1	0	0	**38**
Brakes and servo-brakes	29323020	18	18	1	0	0	**38**
Polypropylene, in primary forms	20165130	0	0	37	0	0	**37**
Metal furniture	31091100	24	12	0	0	0	**36**
Other electric conductors	27321380	0	31	4	0	0	**35**
Parts and accessories	28414030	23	10	1	0	0	**34**
Women's or girls' briefs	14141420	0	0	33	0	0	**33**
Hot rolled concrete rebar	24106210	33	0	0	0	0	**33**
Other wire rod (non-alloy steel)	24106190	32	0	0	0	0	**32**
Portland cement	23511210	0	0	0	0	32	**32**
Parts of air and vacuum pumps	28133200	23	6	1	0	0	**31**
Women's or girls' jerseys	14391072	0	0	29	0	0	**29**
Aluminium structure and parts	25112370	0	29	0	0	0	**29**
Electric motors	27111010	12	16	1	0	0	**29**
Road wheels and parts	29323040	13	14	1	0	0	**28**
Parts for earthmoving equipmt.	28926150	18	8	1	0	0	**27**
Sum total		**1513**	**2557**	**450**	**0**	**32**	**4552**

Table A3. Top 50 commodity groups, ranked by liabilities created at the moment of export, for six materials. Unit: MEUR. Scope: EU28, 2012. Column 2 shows the ProdCom code.

Liability, export, MEUR, EU28, 2012		Steel	Al	Plast.	Paper	Cement	TOTAL
Motor vehicles with petrol eng.	29102230	188	135	49	0	0	**372**
Hot rolled concrete rebar	24106210	240	0	0	0	0	**240**
Aluminium alloy plates, sheets	24422450	0	224	0	0	0	**224**
Flat-rolled products of iron	24103110	185	0	0	0	0	**185**
Portland cement	23511210	0	0	0	0	151	**151**
Industrial use engines	28111375	36	103	1	0	0	**140**
Other trailers and semi-trailers	29202300	65	67	4	0	0	**135**
Flat-rolled products, of iron	24103150	107	0	0	0	0	**107**
Flat semi-finished products	24102110	105	0	0	0	0	**105**
Aluminium foil	24422500	0	101	0	0	0	**101**
Hot dipped metal coated sheet	24105130	91	0	0	0	0	**91**
Cement clinker	23511100	0	0	0	0	83	**83**
Motor vehicles with diesel eng.	29102330	40	29	10	0	0	**80**
Line pipe	24202110	79	0	0	0	0	**79**
Goods vehicles	29104140	46	13	10	0	0	**69**
Parts	28114200	33	34	2	0	0	**69**
Ingots, other primary forms	241021Z0	66	0	0	0	0	**66**
Aluminium alloy bars, rods	24422250	0	61	0	0	0	**61**
Uncoated cold rolled sheet	241041Z0	60	0	0	0	0	**60**
Alternators	27112670	25	33	2	0	0	**59**
Spark-ignition engines	399900Z2	28	29	2	0	0	**58**
Vehicles	29102100	29	21	8	0	0	**58**
Tinplate, other tinned sheet	24105110	58	0	0	0	0	**58**
Other wire rod	24106190	57	0	0	0	0	**57**
Aluminium plates, sheets	24422430	0	57	0	0	0	**57**
H-sections	24107130	56	0	0	0	0	**56**
Polyvinyl chloride	20163010	0	0	54	0	0	**54**
Goods vehicles with diesel eng.	29104110	36	10	8	0	0	**53**
Articles of aluminium, n.e.c.	25992955	0	52	0	0	0	**52**
Parts suitable for machines	27116100	22	29	1	0	0	**52**
Casing, tubing and drill pipe	24201250	52	0	0	0	0	**52**
Unwrought aluminium alloys	24421155	0	52	0	0	0	**52**
Maritime structures	25112355	50	0	0	0	0	**50**
Other electric conductors	27321380	0	44	5	0	0	**49**
Railway material (of steel)	24107500	48	0	0	0	0	**48**
Flat-rolled products	24103510	48	0	0	0	0	**48**
I-sections	24107120	45	0	0	0	0	**45**
Multi-phase AC motors	27112590	19	25	1	0	0	**45**
Polyethylene	20161050	0	0	45	0	0	**45**
Flat-rolled products	24103530	44	0	0	0	0	**44**
Vehicle compression-ign. engs.	29101300	21	21	1	0	0	**43**
Polymers of propylene	20165150	0	0	42	0	0	**42**
Bodies for lorries, vans, buses	29201050	20	20	1	0	0	**41**
Parts for trailers, semi-trailers	29203090	19	20	1	0	0	**40**
Tubes and pipes	24201370	39	0	0	0	0	**39**
Liquid dielectric transformers	27114180	16	21	1	0	0	**38**
Acrylic polymers	20165390	0	0	38	0	0	**38**
Aluminium structure and parts	25112370	0	38	0	0	0	**38**
Synthetic rubber	20171090	0	0	38	0	0	**38**
Sum total		**2070**	**1237**	**360**	**0**	**234**	**3901**

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