

Supporting Information for:

**Dworak, S. & Fellner, J. (2020) Steel Scrap Generation in the EU-28 since 1946 – Sources and Composition.**

This supporting information provides a detailed description of sources and assumptions for the model input data (Part A & Part B). Also included are a detailed description how the transfer coefficients of intermediates into sectors are derived (Part C) and the applied material efficiencies (Part D). Furthermore, the sources and assumptions for the validation of the model are described (Part E).

## **A. Production of steel and steel intermediates, scrap consumption and net import of scrap**

Please find the according numerical data for the part A in the provided spreadsheet: **Table A1: Production of steel and steel intermediates, scrap consumption and net import of scrap of the EU-28 countries** and **Table A2: Rates of production & forming scrap relative to steel used to produce intermediate steel products**

### **1. Total Crude Steel production**

1946 to 1966: USGS Mineral yearbooks for iron and steel (Melcher et al. 1954; Thachter 1968; Whitman 1963).

1967 – 2017: Statistical yearbooks of the World Steel Association ((World Steel Association 1978-2019).

### **2. Scrap Consumption**

1946 to 1966: Assumption that domestic *Scrap Consumption* amounts to about 50% of the *Total Crude Steel* production (justified by Eurostat data (Eurostat 1970) for the EU-6 for the period 1955 – 1966 and data from the World Steel Association for the period 1967 – 1973).

1967 – 2017: Statistical yearbooks of the World Steel Association (World Steel Association 1978-2019).

### **3. Scrap Net Import:**

1946 to 1954: Assumption that the scrap net import amounts to about 5.2% of the domestic *Scrap Consumption*. The 5.2% is the average ratio of *Scrap Net Import* for the years 1955 – 1958.

1955 – 1970: Calculated by subtracting the overall scrap export from the overall scrap import of the EU-28 countries based on data provided by Eurostat (Eurostat 1970).

1971 – 2017: Calculated by subtracting the overall scrap export from the overall scrap import of the EU-28 countries based on data provided by the World Steel Association (World Steel Association 1978-2019).

#### 4. Production & Forming Scrap

1946 to 1951: Assumption that 23% of the *Total Crude Steel Production* arises as Production & forming scrap. The 23% is based on data provided by Eurostat for the EU-6 for the years 1952-1954 (Eurostat 1970).

1952 – 1970: Data about the generation of the *Production & Forming Scrap* for the EU6 (Eurostat 1970), respectively, were scaled up to the “EU-28”, assuming a similar ratio between *Production & Forming Scrap* generation and *Total Crude Steel Production plus net import of Ingots & Semis*.

1971 – 2001: Data about the generation rate of the *Production & Forming Scrap* for the EU6, EU9, EU12 and EU15 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) were related to the respective share of continuous casting steel production in the EU9, EU12 and EU15, as the latter significantly influences the share of Production & Forming scrap (see Figure A1). The so derived linear correlation between both shares was subsequently used to assess the share of *Production & Forming Scrap* for the EU28 using information about the share of continuous casting steel production in the EU28 countries. The latter was obtained from World Steel Statistics.

2002 – 2017: The observed trend for the ratio between *Production & Forming Scrap* and *Total Crude Steel* production for the years 1995 – 2001 was continued until 2017. This resulted in a slight reduction of the ratio to about 8.7% in 2017, as compared to the 10.5% observed for the year 2001.

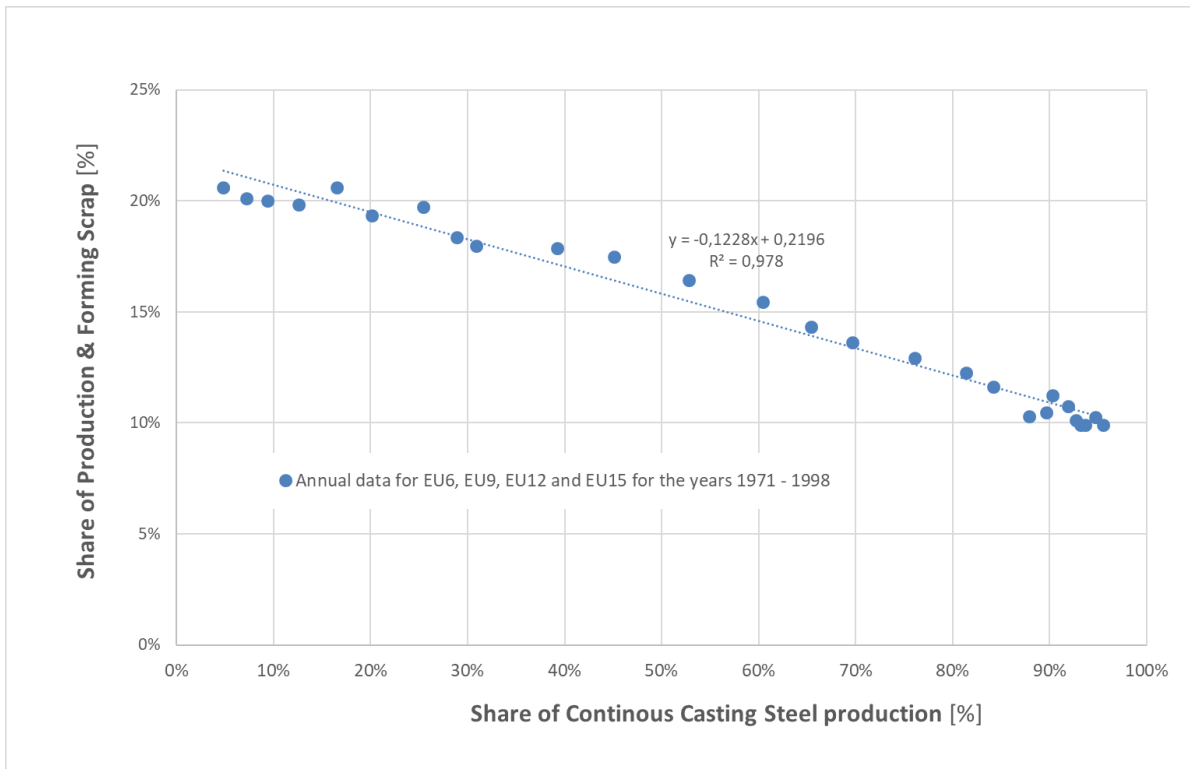


Figure A1 Share of Production & Forming scrap plotted against the share of Continuous Casting Steel production in the EU6, EU9, EU12 und EU15 for the period from 1971 to 1998

**5. Crude Steel (incl. net-import of Ingots & Semis, excl. Production Scrap) = sum of domestic intermediates**

1946 to 2017: Calculated as a difference between the sum of *Total Crude Steel production* (1.) and Net-import of Ingots and Semis (6) and *Production & Forming Scrap* (5.).

**6. Net Import of steel semis ingots & semis**

See section B. *Net Import of steel semis ingots & semis and intermediates*

**7. Cast steel**

1946 to 1951: Assumption that 3.6% of the sum of domestic intermediate steel products are used for *Cast Steel*. The 3.6% ratio has been determined by using Eurostat data for the years 1952 – 1953 for the EU6 (Eurostat 1964).

1952 – 1986: Data about the generation of the production of *Cast Steel* reported for the EU6, EU9, EU12 and EU15 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002), respectively, were scaled up to the “EU-28”, assuming a similar ratio between

the production of steel castings and the sum of domestic intermediate steel products.

1987 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by the European Foundry Association (CAEF 2008 - 2018).

## 8. Cast Iron

1946 to 1949: Assumption that cast iron production amounts to about 11.2% of total crude steel production. The ratio of 11.2% ratio has been derived using data for Germany, which generates about 1/3 of the overall *Cast Iron* volume in the EU-28. Eurostat data for the years 1955 – 1958 was used for the EU6 (Eurostat 1964).

1950 – 1966: For this period, data for Germany was available from the Federal Association for the German Foundry Industry (published in (Meuselwitz 2009)). This production data was up-scaled to the EU-28, assuming that the German production amounts to about 1/3 of the EU-28's *Cast Iron* production. This share of 1/3 has been derived from global production statistics for *Cast Iron* reported for the years 1967 to 2003.

1967 – 2003: Data about the production of *Cast Iron* reported in (Modern Casting 1967 - 2003) have been used.

2004 – 2017: Data provided by the European Foundry Association (CAEF 2008 - 2018).

## 9. Electrical Strip

1946 to 1951: Assumption that 0.56% of the sum of domestic intermediate steel products are used for *Electrical Strips*. The ratio of 0.56% ratio is based on a reported share of 0.7% for the EU6 for the years 1952 – 1955 (Eurostat 1964). However, since a higher share of *Electrical Strip* production is expected in the EU-6 than for the "EU-28", the reported share for the EU6 has been reduced by 20%. ( $0.56\% = 0.7\% * 0.8$ )

1952 – 1983: Ratios for *Electrical Strip* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Electrical Strips*. The ratios reported however have been reduced by 20%, since a higher share of *Electrical Strip* production is expected for the EU-6, EU-9, EU-12 than for the "EU-28". This reduction of 20% in the relative share of *Electrical Strip*

production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1984 – 1988.

1984 – 2017: Data provided by the World Steel Association (World Steel Association 1978-2019).

## 10. Tin plated

1946 to 1951: Assumption that 1.06% of the sum of domestic intermediate steel products are used for the intermediate *Tin Plated*. The ratio of 1.06% ratio is based on a reported share of 1.56% for the EU6 for the years 1952 – 1955 (Eurostat 1964). However, since a higher share of *Tin Plated* production is expected in the EU-6 than in the “EU-28” the reported share for the EU6 has been reduced by 32%. ( $1.06\% = 1.56\% * 0.68$ ).

1952 – 1983: Ratios for *Tin Plated* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Tin Plated*. The ratios reported however have been reduced by 32%, since a higher share of *Tin Plated* is expected for the EU-6, EU-9, EU-12 than for the “EU-28”. This reduction in the relative share of *Tin Plated* production by 32% is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1984 – 1988.

1984 – 2017: Data provided by the World Steel Association (World Steel Association 1978-2019).

## 11. Plate (excl. plate used for welded tubes)

1946 to 1951: Assumption that 16.4% of the sum of domestic intermediates is used for *Plate* (excl. plates used for welded tubes). The ratio of 16.4% ratio is based on a reported share of 13.7% for the EU6 for the years 1952 – 1955 (Eurostat 1964). However, since a lower share of *Plate* production is expected in the EU-6 than in the “EU-28” the reported share for the EU6 has been increased by 20%. ( $16.4\% = 13.7\% * 1.2$ ).

1952 – 2002: Ratios for *Plate* (excl. intermediates for welded tubes) production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production

of *Plate*. The ratios reported however have been increased by 20%, since a lower share of plates is expected for the EU-6, EU-9, EU-12 than for the “EU-28”. This increase of 20% in the relative share of *Plate* production is based on a comparison between Eurofer data reported for the EU-28 countries for 2004 - 2006 and scaled up Eurostat data for the EU-15 for the years 2000 - 2002.

2003: Interpolated between Eurostat based data for the year 2002 (Eurostat 2002) and EUROFER data for the year 2004 (Eurofer 2009).

2004 – 2017 Production data for *Plate* reported by Eurofer (Eurofer 2018a, 2009) have been reduced by the share of plates used for welded tubes (also reported by Eurofer) to derive the annual quantities of *Plate* (excl. intermediates for welded tubes)

## 12. Cold Rolled Coil galvanized

1946 to 1951: Assumption that 1.0% of the sum of domestic intermediate steel products is used for *Cold Rolled Coil galvanized*. The ratio of 1.0% ratio is based on a reported share of 1.1% for the EU6 for the years 1952 – 1955 (Eurostat 1964). However, since a higher share of *Cold Rolled Coil galvanized* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been reduced by 10% ( $1.0\% = 1.1\% * 0.9$ ).

1952 – 1983: Ratios for *Cold Rolled Coil galvanized* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Cold Rolled Coil galvanized*. The ratios reported however have been reduced by 10%, since a higher share of *Cold Rolled Coil galvanized* is expected for the EU-6, EU-9, EU-12 than for the “EU-28”. This reduction in the relative share of *Cold Rolled Coil galvanized* production by 10% is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1984 – 1988.

1984 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by Eurofer (Eurofer 2018a, 2009).

## 13. Cold Rolled Coil coated

1946 to 1951: Assumption that 0.2% of the sum of domestic intermediate steel products is used for *Cold Rolled Coil coated*. The ratio of 0.2% ratio is based on a reported share for the EU6 for the years 1952 – 1955 (Eurostat 1964).

1952 – 1991: Ratios for *Cold Rolled Coil coated* production in relation to the sum of domestic intermediates for the EU-6, EU-9, and EU-12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Cold Rolled Coil coated*. Unlike for *Plate, Cold Rolled Coils coated*, no reduction in the relative share of *Cold Rolled Coil coated* production was conducted for the EU-28 in comparison to the EU-6, EU-9, EU-12 This was because scaled up Eurostat data for the EU-12 for the years 1992 – 1995 already fit well to the data reported for the EU-28 by the World Steel Association (World Steel Association 1978-2019).

1992 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by Eurofer (Eurofer 2018a, 2009).

#### **14. Cold Rolled Coil**

1946 to 1951: Assumption that 3.6% of the sum of domestic intermediate steel products is used for *Cold Rolled Coil*. The ratio of 3.6% ratio is based on a reported share of 4.0% for the EU6 for the years 1952 – 1955 (Eurostat 1964). However, since a higher share of *Cold Rolled Coil* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been reduced by 10%. ( $3.6\% = 4.0\% * 0.9$ ).

1952 – 2002: Ratios for *Cold Rolled Coil* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Cold Rolled Coil*. The ratios reported however have been reduced by 10%, since a lower share of *Cold Rolled Coil* is expected for the EU-6, EU-9, EU-12 than for the “EU-28”. This reduction of 10% in the relative share of *Cold Rolled Coil* production is based on a comparison between EUROFER-based data for the EU-28 countries for 2004 - 2006 (see data description for the period 2004 to 2017) and scaled up Eurostat data for the EU-15 for the years 2000 - 2002.

2003: Interpolated between Eurostat-based data for the year 2002 (Eurostat 2002) and EUROFER-based data for the year 2004 (Eurofer 2009).



2004 – 2017 Production data for *Cold Rolled Coil* have been calculated based on data reported by Eurofer (Eurofer 2018a, 2009) for the overall production of cold rolled flat products and the quantities of other cold rolled products (*Cold Rolled Coil galvanized, Cold Rolled Coil coated, Tin Plated and Electrical Strip*).

## **15. Hot Rolled Coil galvanized**

1946 to 1951: Assumption that 0.12% of the sum of domestic intermediates is used for *Hot Rolled Coil galvanized*. The ratio of 0.12% ratio is based on a reported share of 0.12% for the EU6 for the years 1952 – 1955 (Eurostat 1964).

1952 – 2002: Ratios for *Hot Rolled Coil galvanized* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Hot Rolled Coil galvanized*.

2003 – 2017: Based on Eurostat data reported for the years 1998 – 2002, a relative share of 1.4% for the production of *Hot Rolled Coil galvanized* has been assumed. Since no statistical data were available for this period, the share of 1.4% has been assumed to be constant for the entire period.

## **16. Hot Rolled Narrow Strip (excl. strips used for welded tubes)**

1946 to 1951: Assumption that 6.0% of the sum of domestic intermediates is used for *Hot Rolled Narrow Strip*. The ratio of 6% ratio is based on a reported data for the EU6 for the years 1952 – 1955 (Eurostat 1964).

1952 – 1985: Ratios for *Hot Rolled Narrow Strip* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Hot Rolled Narrow Strip*. The so calculated quantities were reduced by about 12% in order to account for the fact, that some *Hot Rolled Narrow Strip* is used by the steel tube industry (welded tubes). The 12% reduction is based on the average data reported by Eurofer for the period 2004 to 2017 (Eurofer 2018a, 2009).

1986 - 2003: Data reported by the World Steel Association for the EU-28 countries has been reduced by 12% to account for the consumption of *Hot Rolled Narrow Strip* in the steel tube industry (World Steel Association 1978-2019).

2004 – 2017: Production data for *Hot Rolled Narrow Strip* reported by Eurofer have been reduced by the amount reported by Eurofer to be used in the steel tube industry (welded tubes) (Eurofer 2018a, 2009).

## 17. Hot Rolled Coil

1946 to 1951: Assumption that 4.0% of the sum of domestic intermediates is used for *Hot Rolled Coil*. The ratio of 4% ratio is based on reported data for the EU6 for the years 1952 – 1953 (Eurostat 1964).

1952 – 2017: The production of *Hot Rolled Coil* was determined by balancing the overall production of intermediates (*6. Crude steel production excluding production (internal) scrap = sum of domestic intermediates*) and the production of all intermediates with the exception of *Hot Rolled Coil*. To crosscheck the so derived production data for *Hot Rolled Coil*, its production has also been estimated using reported shares of *Hot Rolled Coil* in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002). The comparison between both approaches showed they aligned with one another accordingly. The relative deviation in both data sets was below 15%, indicating the appropriateness of the chosen approach.

## 18. Welded Tubes

1946 to 1954: Assumption that 2.7% of the sum of domestic intermediates is used for *Welded Tubes*. The ratio of 2.7% is based on a reported share of 3.0% for the EU6 for the years 1955 – 1960 (Eurostat 1964). However, since a higher share of *Welded Tubes* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been reduced by 10%. ( $2.7\% = 3.0\% \cdot 0.9$ ).

1955 – 1980: Ratios for *Welded Tubes* production in relation to the sum of domestic intermediates for the EU-6, EU-9, and EU-12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Welded Tubes* for the EU-28. The ratios reported however have been reduced by 10%, since a higher share of *Welded Tubes* is expected for the EU-6, EU-9, EU-12 than for the “EU-28”. This reduction of 10% in the relative share of *Welded Tubes* production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1981 – 1985.

1981 – 2017: Data provided by the World Steel Association (World Steel Association 1978-2019).

## 19. Seamless Tubes

1946 to 1954: Assumption that 5.9% of the sum of domestic intermediates is used for *Seamless Tubes*. The ratio of 5.9% is based on a reported share of 5.6% for the EU6 for the years 1955 – 1960 (Eurostat 1964). However, since a lower share of *Seamless Tubes* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been increased by 5%. ( $5.9\% = 5.6\% * 1.05$ ).

1955 – 1980: Ratios for *Seamless Tubes* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Seamless Tubes* for the EU-28. The ratios reported however have been increased by 5%, since a lower share of *Seamless Tubes* is expected for the EU-6, EU-9, EU-12 than for the “EU-28”. This 5% increase in the relative share of *Seamless Tubes* production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1981 – 1985.

1981 – 2017: Data provided by the World Steel Association (World Steel Association 1978-2019).

## 20. Wire Rod

1946 to 1951: Assumption that 7.7% of the sum of domestic intermediates is used for *Wire Rod*. The ratio of 7.7% is based on a reported share of 8.7% for the EU6 for the years 1952 – 1954 (Eurostat 1964). However, since a higher share of *Wire Rod* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been reduced by 12% ( $7.7\% = 8.7\% * 0.88$ ).

1952 – 1983: Ratios for *Wire Rod* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Wire Rod* for the EU-28. The ratios reported however have been reduced by 12%, since a higher share of *Wire Rod* is expected for the EU-6, EU-9, EU-12 than for the EU-28. This reduction of 12% in the relative share of *Wire Rod* production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1984 – 1988.

1984 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by Eurofer (Eurofer 2018a, 2009).

## 21. Reinforcing Bar

1946 to 1951: Assumption that 10.8% of the sum of domestic intermediates is used for *Reinforcing Bar*. The ratio of 10.8% is based on a reported share of 12.3% for the EU6 for the years 1952 – 1954 (Eurostat 1964). However, since a higher share of *Reinforcing Bar* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been reduced by 12% ( $10.8\% = 12.3\% * 0.88$ ).

1952 – 1984: Ratios for *Reinforcing Bar* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Reinforcing Bar* for the EU-28. The ratios reported however have been reduced by 12%, since a higher share of *Reinforcing Bar* is expected for the EU-6, EU-9, EU-12 than for the EU-28. This reduction of 12% in the relative share of *Reinforcing Bar* production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1985 – 1989.

1985 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by Eurofer (Eurofer 2018a, 2009).

## 22. Hot Rolled Bar

1946 to 1951: Assumption that 14.4% of the sum of domestic intermediates is used for *Hot Rolled Bar*. The ratio of 14.4% is based on a reported share of 12.0% for the EU6 for the years 1952 – 1954 (Eurostat 1964). However, since a lower share of *Hot Rolled Bar* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been increased by 20% ( $14.4\% = 12.0\% * 1.2$ ).

1952 – 1983: Ratios for *Hot Rolled Bar* production in relation to the sum of domestic intermediates for the EU-6, EU-9, EU-12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Hot Rolled Bar* for the EU-28. The ratios reported for the EU-6, EU-9, EU-12 however have been increased by 20%, since a lower share of *Hot Rolled Bar* is expected for the EU-6, EU-9, EU-12 than for the EU-28. This increase by 20% in the relative share of *Hot Rolled Bar* production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1984 – 1988.

1984 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by Eurofer (Eurofer 2018a, 2009).

### **23. Heavy Section**

1946 to 1951: Assumption that 10.8% of the sum of domestic intermediates is used for *Heavy Section*. The ratio of 10.8% is based on a reported share of 8.3% for the EU6 for the years 1952 – 1954 (Eurostat 1964). However, since a lower share of *Heavy Section* production is expected in the EU-6 than in the “EU-28”, the reported share for the EU6 has been increased by 30% ( $10.8\% = 8.3\% \times 1.3$ ).

1952 – 1983: Ratios for *Heavy Section* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Heavy Section* for the EU-28. The ratios reported however have been increased by 30%, since a lower share of *Heavy Section* is expected for the EU-6, EU-9, EU-12 than for the EU-28. This increase by 30% in the relative share of *Heavy Section* production is based on a comparison between World Steel data reported for the EU-28 countries and scaled up Eurostat data for the EU-12 for the years 1984 – 1988.

1984 – 2003: Data provided by the World Steel Association (World Steel Association 1978-2019).

2004 – 2017: Data provided by Eurofer (Eurofer 2018a, 2009).

### **24. Light Section**

1946 to 1951: Assumption that 6.4% of the sum of domestic intermediates is used for *Light Section*. The ratio of 6.4% is based on a reported share for the EU6 for the years 1952 – 1954 (Eurostat 1964).

1952 – 1986: Ratios for *Light Section* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Light Section* for the EU-28. Unlike to many other intermediates, no reduction or increase in the relative share of *Light Section* production was conducted for the EU-28 in comparison to the EU-6, EU-9, EU-12, since scaled up Eurostat data for the EU-12 for the years 1987 – 1991 fit well to data reported for the EU-28 by the World Steel Association (World Steel Association 1978-2019).

1987 – 2002: Data provided by the World Steel Association (World Steel Association 1978-2019).

2003 – 2017: Due to missing statistical data, a constant production of *Light Section* of 3.5 Mt/yr was assumed. This amount corresponds to the average production in the years 1996 - 2002.

## **25. Rail Section**

1946 to 1951: Assumption that 4.4% of the sum of domestic intermediates is used for *Rail Section*. The ratio of 4.4% is based on a reported share for the EU6 for the years 1952 – 1954 (Eurostat 1964).

1952 – 1983: Ratios for *Rail Section* production in relation to the sum of domestic intermediates for the EU6, EU9, and EU12 (Eurostat 1970, 1977, 1985, 1994, 1998, 2002) have been used to assess the production of *Rail Section* for the EU-28. Unlike to many other intermediates, no reduction or increase in the relative share of *Rail Section* production was conducted for the EU-28 in comparison to the EU-6, EU-9, EU-12, since scaled up Eurostat data for the EU-12 for the years 1984 – 1988 fit well to data reported for the EU-28 by the World Steel Association (World Steel Association 1978-2019).

1984 – 2017: Data provided by the World Steel Association (World Steel Association 1978-2019).

## B. Net Import of steel ingots & semis and intermediates

Please find the according numerical data for the part B in the provided spreadsheet: **Table B1: Net import of steel ingots & semis and intermediates into the EU-28 countries**

### 1994 – 2017:

For the net import of ingots & semis and the different steel intermediates for the period 1994 to 2017, the import and export of (e.g. Welded tubes, Cast Steel, Cold Rolled Coil) for each EU-28 member country has been taken from the UN Comtrade database (UN Comtrade 2020).

In Table B1 below, the requested HS-codes (Harmonized Commodity Description and Coding System) for the steel intermediates are summarized, indicating that for this period net import data on the level of the different intermediates were “directly” available.

### 1946 – 1993:

Information about the overall net import of ingots & semis and steel intermediates into the EU-28 were derived for the years 1950 – 1967 from regional data of ingot & semis and intermediate imports and exports (EU9, Western Europe, Eastern Europe). For the years 1968 to 1993, import and export data of all member countries of the EU-28 have been aggregated to derive information about the net import of ingots & semis and steel intermediates. All of this data was taken from the Statistical Yearbooks of the World Steel Association (World Steel Association 1978-2019).

For the years 1946 to 1949, no information was available, therefore it was assumed that the net import of semis & ingots and intermediate steel products amounted to -9% of the overall domestic production of all intermediates during this period. This rate of -9% represents the average for the years 1950 – 1954.

In order to obtain information about the net import of ingots & semis and the single steel intermediates for the years 1946 – 1993, they have been grouped into three categories:

Category A: Ingots & semis and Intermediates for which information about the global export rate (share related to the overall global export of ingot & semis and intermediates) was available from World Steel statistics for the years 1950 – 1981 (World Steel Association 1978-2019). They include *Semis & Ingots, Heavy Section, Light Section, Rail Section, Wire Rod, Hot Rolled Bar & Reinforcing Bar*<sup>1</sup>,

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<sup>1</sup> Only figures for both together were available. Hence, the shares of export given for both have being split according to the domestic production rates of both intermediates

*Hot Rolled Narrow Strip, Seamless & Welded Tubes<sup>2</sup>, Plate, and Tin Plated.* For the years 1946 to 1949, the same distribution among the different intermediates was assumed as for the year 1950, whereas for the years 1982 to 1993, a linear interpolation between reported global export shares of the different intermediates (average for years 1977 - 1981) and the shares of intermediates derived from the UN Comtrade database (average for years 1994 - 1998) was accomplished.

Category B: Intermediates for which no information about the global export rate was available, but with rather constant or a low share of net export during the years 1994 – 2000. They include *Cast steel, Cast Iron, Cold Rolled Coil coated. Hot Rolled galvanized.*

Category C: Intermediates for which no information about the global export rate was available for the years 1950 – 1981. They include *Hot Rolled Coil, Cold Rolled Coil, Cold Rolled Coil galvanized, and Cold Rolled Coil coated.*

For category A intermediates and ingots & semis, the reported/interpolated shares of the global export rate have been assumed to be representative for the net import of the EU-28. Hence, the net import of these intermediates (in 1,000 t/yr) has been estimated by multiplying the respective global export rate of the intermediates with the overall net import of ingot & semis and intermediates into the EU-28.

For category B intermediates, a constant net import share (share of specific intermediate net import in relation to the overall net import of all ingot & semis and intermediates) was assumed for the period 1946 – 1993. These respective net import shares were derived from the average shares from the period 1994 – 1998. These shares were subsequently multiplied with the overall amount of net import of all ingot & semis and intermediates to derive the specific net import of the respective steel intermediate (given in 1,000 t/yr).

For category C intermediates, the sum of net imports was determined by balancing the overall net-export of all ingot & semis and intermediates (derived from World Steel Statistics (World Steel Association 1978-2019)) with the sum of net import of category A and B ingot & semis and intermediates . This sum was subsequently divided into the different intermediate categories according to their domestic production volume.



In addition to the calculations given above, detailed data for the net imports into the EU-28 of the following intermediates, namely *Wire Rod*, *Seamless Tubes*, *Welded Tubes*, *Tin Plated* and *Cold Rolled Coil galvanized*, were available from World Steel Statistics (World Steel Association 1978-2019) for the years 1984 to 1993.

**Table B1: HS-Codes and corresponding Ingots & Semis and intermediate steel products**

	<b>Ingots &amp; Semis and intermediate steel products</b>	<b>HS-Code</b>
6	Ingots & Semis	720610, 720690, 720711, 720712, 720719, 720720, 721810, 721891, 721899, 722410, 722490
7	Cast steel	732619
8	Cast Iron	730300, 730711, 730719, 732510, 732591, 732599
9	Electrical Strip	722511, 722519, 722611, 722619
10	Tin Plated	721011, 721012, 721210
11	Plate	720840, 720851, 720852, 720853, 720890, 722540, 722599
12	Cold Rolled Coil galvanized	721020, 721030, 721041, 721049, 721050, 721061, 721090, 721220, 721230, 721250, 722591, 722592
14	Cold Rolled Coil coated	721070, 721240
15	Cold Rolled Coil	720915, 720916, 720917, 720918, 720925, 720926, 720927, 720928, 720990, 721123, 721129, 721190, 721931, 721932, 721933, 721934, 721935, 722020, 722550, 722692
16	Hot Rolled Narrow Strip	721113, 721114, 721119
17	Hot Rolled Coil	720810, 720825, 720826, 720827, 720836, 720837, 720838, 720839, 720854, 721069, 721260, 721911, 721912, 721913, 721914, 721921, 721922, 721923, 721924, 721990, 722011, 722012, 722090, 722530, 722620, 722691, 722699
18	Welded Tube	730511, 730512, 730519, 730520, 730531, 730539, 730590, 730611, 730619, 730621, 730629, 730630, 730640, 730650, 730661, 730669, 730690, 730723, 730792, 730793, 730799
19	Seamless tube	730411, 730419, 730422, 730423, 730424, 730429, 730431, 730439, 730441, 730449, 730451, 730459, 730490, 730721, 730722, 730729, 730791
20	Wire Rod	721710, 721720, 721730, 721790, 722100, 722300, 722920, 722990
21	Reinforcing bar	721310, 721420, 721499
22	Hot Rolled Bar	721320, 721391, 721399, 721410, 721430, 721491, 721510, 721550, 721590, 722211, 722219, 722220, 722230, 722710, 722720, 722790, 722810, 722820, 722830, 722840, 722850, 722860, 722880
23	Heavy section	721631, 721632, 721633, 721640, 730110
24	Light Section	721610, 721621, 721622, 721650, 721661, 721669, 721691, 721699, 722240, 722870, 730120
25	Rail section	730210, 730230, 730240, 730290

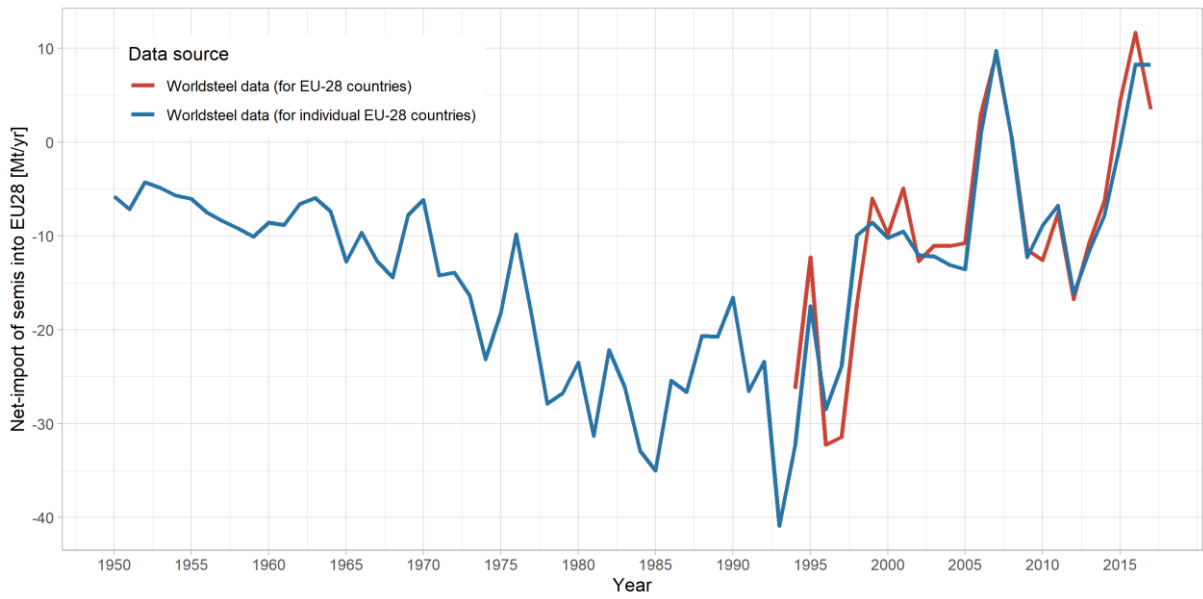


Figure B1 Overall net import of Ingots & semis and steel intermediates into the EU-28 for the period 1950 to 2017 (the blue line indicates bottom up data derived from the UN Comtrade database for the years 1994 - 2017, whereas the red line is based on World Steel Statistics regarding the overall import and export of Ingot & semis and steel intermediates for the years 1950 – 2017)

## C. Derivation of transfer coefficients for steel intermediates

Please find the according numerical data for the part C in the provided spreadsheet: **Table C1: Transfer coefficients of steel for the different end-use sectors** and **Table C2: Initial estimates for intermediate specific transfer coefficients**.

For the sum of domestically produced intermediates and net import of intermediates, transfer coefficients assigning the 19 intermediates to the 10 end-use sectors have been applied. These transfer coefficients are not constant over time, as the steel end-use has changed significantly since 1946.

In the following section, the derivation/calculation of transfer coefficients for each steel intermediate is described.

### C1. Initial estimates for the transfer coefficients for steel intermediates

For all intermediates - except for most flats, namely *Cold Rolled Coil*, *Cold Rolled Coil galvanized*, *Cold Rolled Coil coated*, *Hot Rolled Coil*, *Hot Rolled Narrow Strip*, and *Plate* – initial estimates for the transfer coefficients were taken from (Cullen et al. 2012) to assess the distribution of the steel intermediates to the different end-use sectors. For the flats *Cold Rolled Coil*, *Cold Rolled Coil galvanized*, *Cold Rolled Coil coated*, *Hot Rolled Coil*, *Hot Rolled Narrow Strip*, and *Plate*, the initial estimates for the transfer coefficients were derived from data published by Eurofer (Eurofer 2018b) for the years 2004 – 2017.

### C2. Share of steel end-use in the different sectors

In addition to the intermediate-specific transfer coefficients, information about the relative share of the steel consumption in the 10 end-use sectors was collected for different years. Data about the steel end-use published in the Official Journal of the European Commission (European Commission 1966, 1976, 1985, 1990) for the EU6, EU9, EU12 and EU15, respectively; data given by Eurofer (Eurofer 2018a); and estimates<sup>2</sup> about the steel end-use in non EU-countries at the respective times (mainly for Eastern European countries)) have been used/combined (see Table C1 provided in spreadsheet). Based on the different data sources, the share of steel end-use (given in % of the overall steel consumption) in the 10 sectors was assessed for the years 1960, 1972, 1981, 1987, 1992, 1995 and 2017. In between these years,

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<sup>2</sup> The estimates are based on steel end-use data for emerging economies, such as India (IBEF 2014) and historical data for the steel use (incl. for instance vehicle production) in individual Eastern European countries ((Patmann et al. 1974; Montias 1957) Furthermore, the estimates for non-EU countries at the respective time are based on own assumptions.

the respective shares of the sectoral steel end-use was interpolated. For the years 1946 – 1959, the shares determined for 1960 were assumed, as no other information was available.

### C3. Assessment of annual values for the transfer coefficients for steel intermediates

In a first step, the initial values for the intermediate-specific transfer coefficients (mix of Eurofer- and Cullen-based data – see point C1) were applied to the annual quantities of steel intermediates in order to calculate the transfer of steel to the 10 end-use sectors. In a second step, the so obtained estimates for the sectoral distribution of the final steel use were compared to the “reported” shares of steel end-use in the 10 sectors (data described under point C2). The comparison of simulation results with the “reported” data (point C2) on the sectoral share of steel end-use made it possible to derive correction factors for the intermediate-specific transfer coefficients. For instance, if for the building sector the model (simulation) results gave a share of steel end-use of 22%, and the “statistically”-derived data suggested a share of 28%, then the transfer coefficients for all intermediates delivered to the buildings sector were multiplied by  $28/22=1.27$  (i.e., the correction factor). The same was done for all other intermediate-specific transfer coefficients. They were either simultaneously (for the respective sector) increased or decreased by applying the correction factors derived by the comparing model results with the “reported” shares of sectoral end-uses of steel. Since the so corrected specific transfer coefficients did not sum up to 1 for each intermediate as required, a scaling to 1 was conducted in a third step. The corrected specific transfer coefficients were then divided by the sum of the transfer coefficients for each intermediate.

The so obtained corrected and scaled transfer coefficients for each intermediate were subsequently used<sup>3</sup> to calculate the distribution of steel to the different end-use sectors (see step 1). The thereby obtained results were again compared to the “reported” data (point C2) on the sectoral share of steel end-use in order to derive the correction factors for the transfer coefficients (see step 2) and to subsequently scale them (step 3).

This procedure (step 1: simulation, step 2: comparison of model and reported data for derivation of correction factors for transfer coefficients, step 3: scaling of correction factors)

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<sup>3</sup> Instead of the initial estimates of the intermediate-specific transfer coefficients (see point C1)

was repeated several times until the difference between the shares of simulated and reported sectoral steel end-use was sufficiently insignificant.

For the data used (see point C1 and C2) in the frame of the present work, 3 to 6 iterations were generally sufficient to achieve deviations between the simulated and “reported” shares of sectoral end-use of steel below 0.05%. The latter was used as abort criterion for the iteration procedure.

A summary of the iteration process results, especially the temporal developments of each transfer coefficient (intermediate-specific transfer coefficients), is given in Figure C1, C2, C3, and C4.

These specific transfer coefficients (for each year) were then used to simulate the steel flows of each intermediate and their respective transfers into the end-use sectors and their associated generation of fabrication scrap. For the latter, the gross flows of intermediates into each sector were multiplied by the respective material efficiencies (given in Table D1 provided in spreadsheet).

**Figure C1 Transfer coefficients of steel intermediates into Buildings and Infrastructure (for the years 1946 to 2017)**

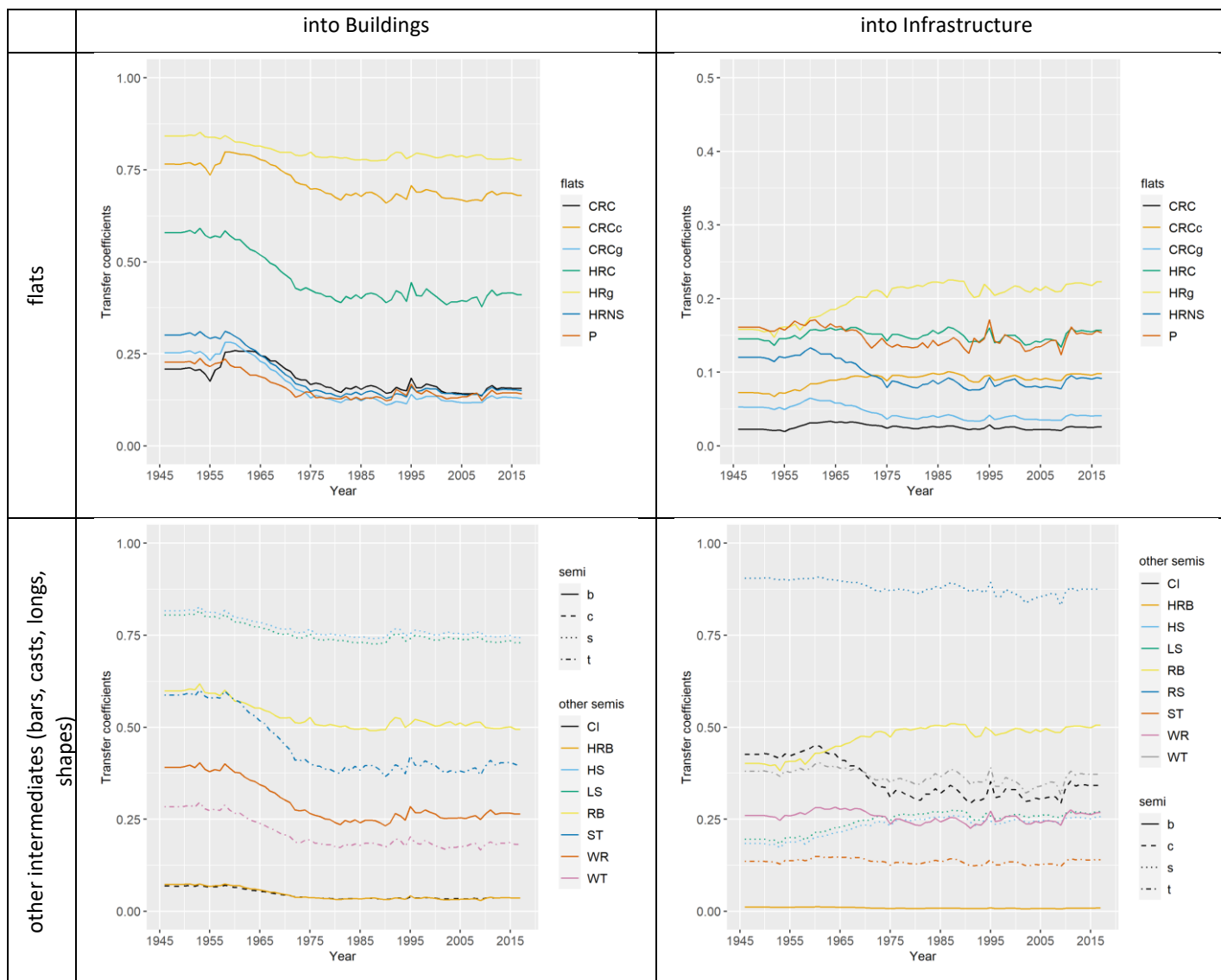
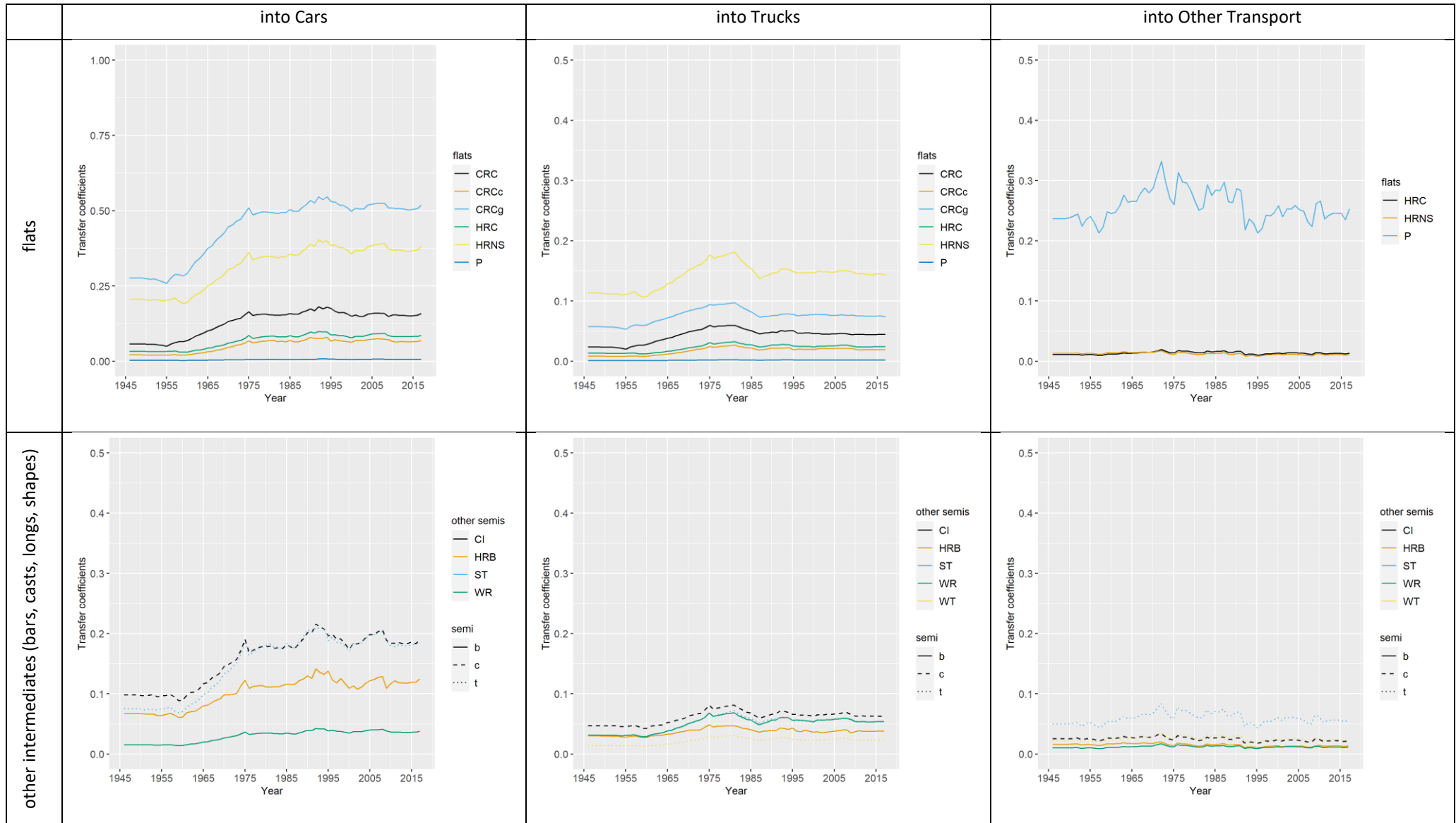
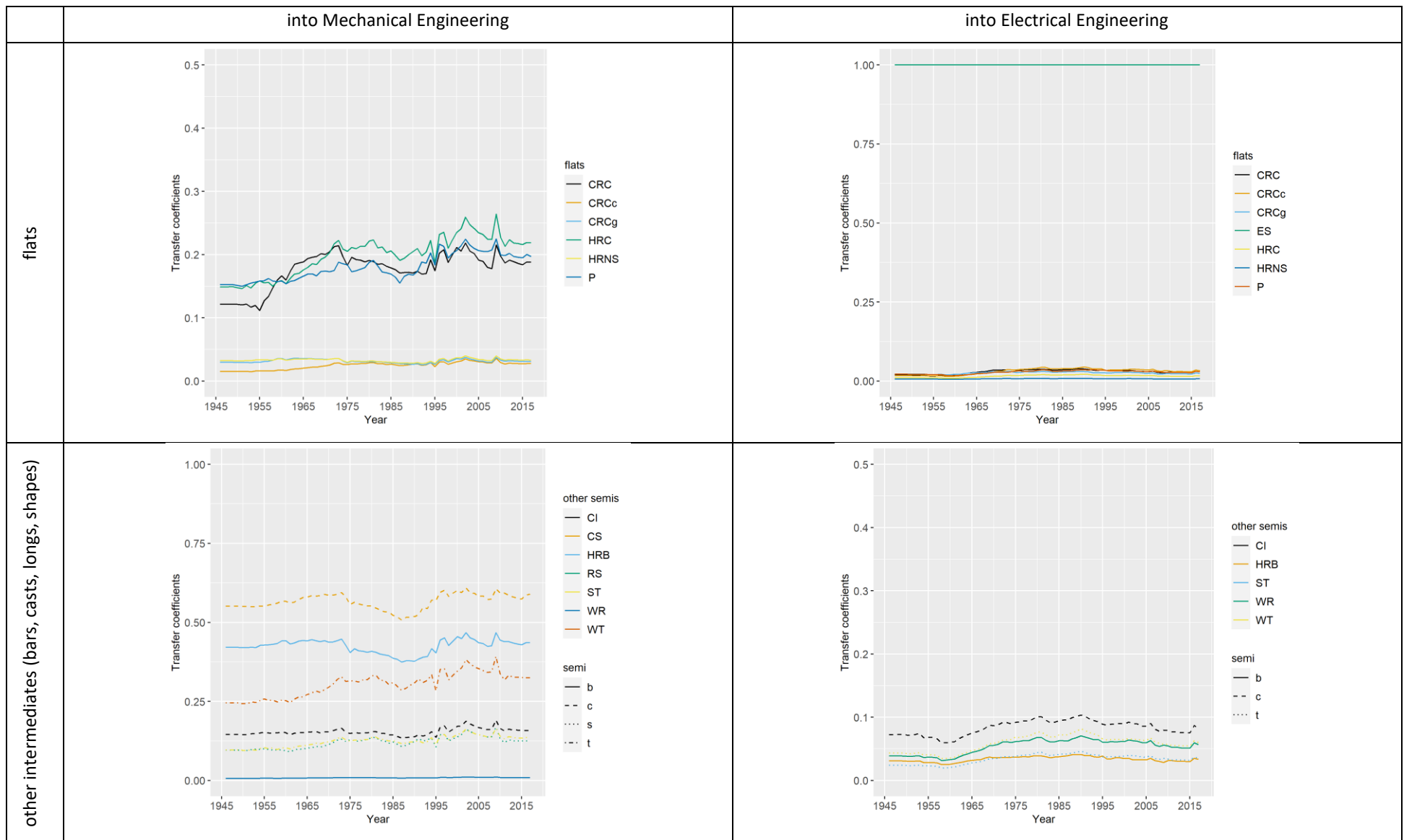


Figure C2 Transfer coefficients of steel intermediates into Cars, Trucks and Other Transport (for the years 1946 to 2017)

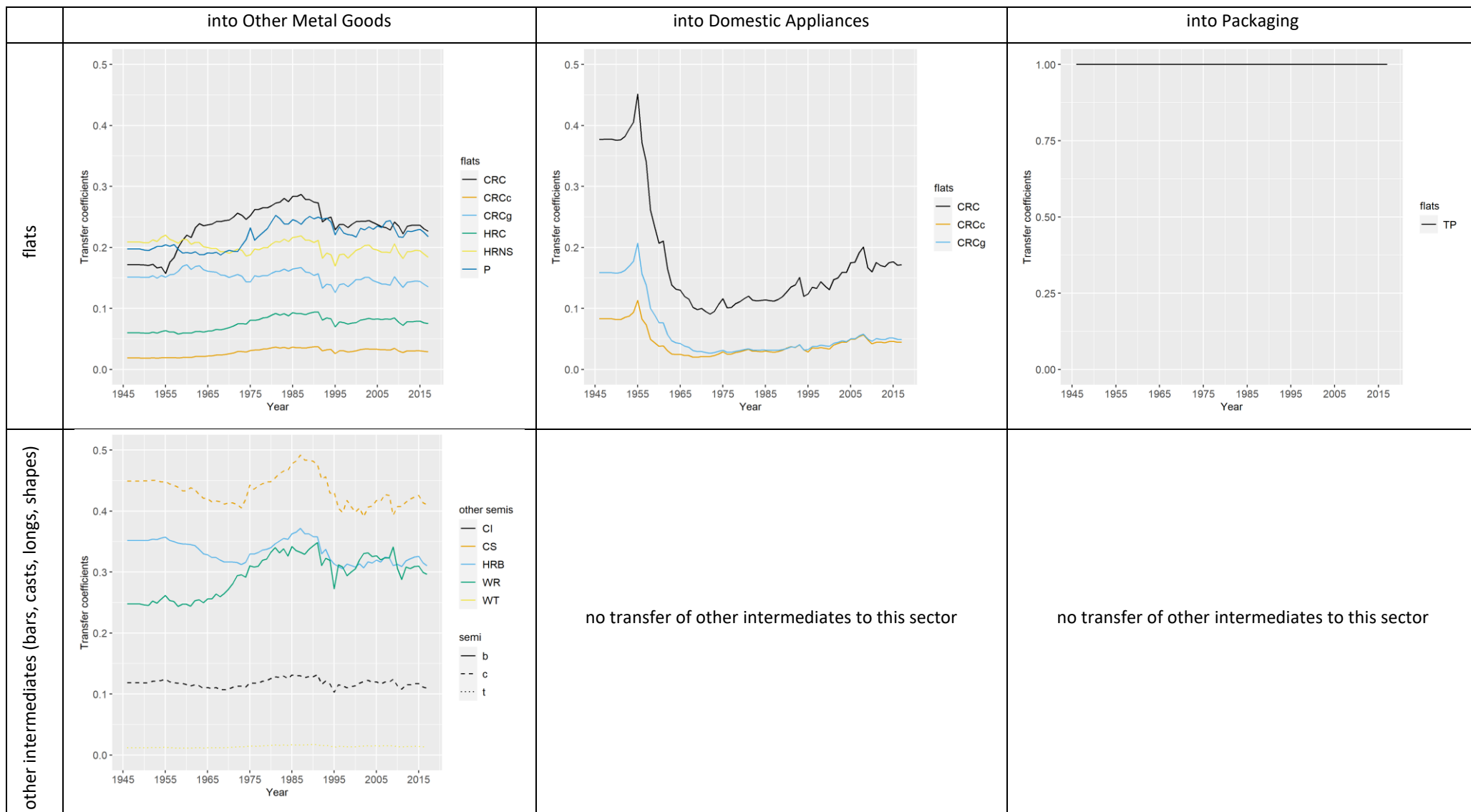




**Figure C3 Transfer coefficients of steel intermediates into Mechanical Engineering and Electrical Engineering (for the years 1946 to 2017)**



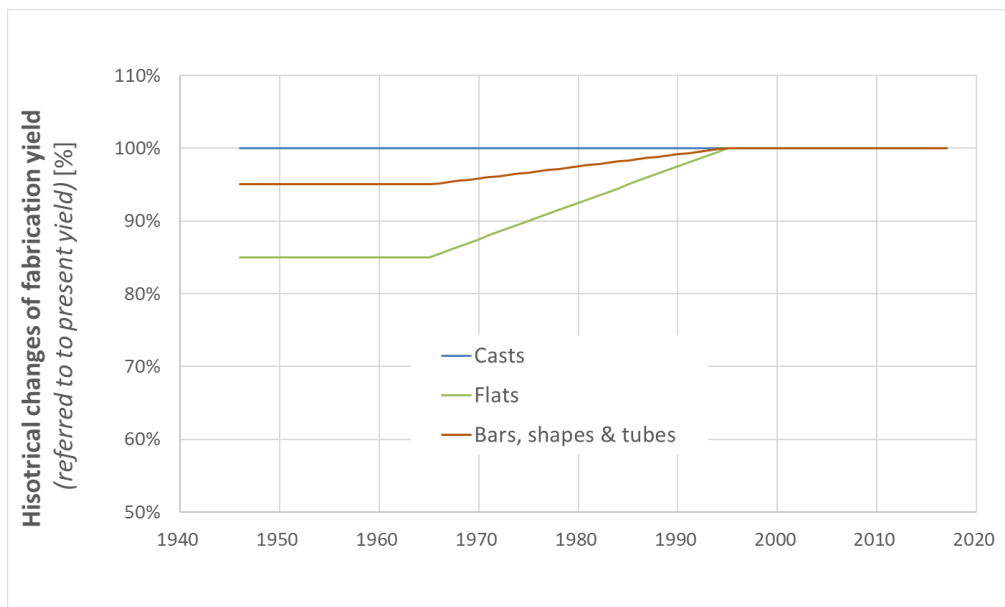
**Figure C4 Transfer coefficients of steel intermediates into Other Metal Goods, Domestic Appliances and Packaging (for the years 1946 to 2017)**



## D. Material Efficiencies for the Processing of Steel Intermediates

Please find the according numerical data for the part D in the provided spreadsheet: **Table D1: Material efficiencies for the different steel intermediates processed into final goods.**

The material efficiencies (and thus the generation of fabrication scrap) during the processing of steel intermediates into final goods have been taken from Cullen et al. (2012) and supplemented by own estimates where necessary (see Table D1 provided in spreadsheet). For the own estimates, the average material efficiency for flats in the respective sector has been assumed. For the period 1995 – 2017, constant material efficiencies (see Table D1) have been assumed, whereas for the years 1965 to 1995 a steadily improvement<sup>4</sup> of the material efficiencies was assumed according to data provided in (Pauliuk et al. 2013). In particular, different temporal developments of the fabrication yield for casts, flats, and bars, tubes & shapes have been assumed (see Figure D1).



**Figure D1** Assumed temporal development of the fabrication yield of different intermediates referred to the present yield (given in %)

<sup>4</sup> reduction if referred to current efficiencies

## E. Steel qualities

Table E1 Steel qualities (with respect to the tolerance level of the tramp elements Cr, Ni, Cu, Sn and Mo) for each intermediate to end-use sector

		Buildings	Infra-structure	Cars	Trucks	Other Transport	Mechanical Engineering	Electrical Engineering	Other Metal Goods	Domestic appliances	Packaging
9	Electrical Strip							Q1			
10	Tin plated										Q1
11	Plate	Q3	Q3	Q2	Q2	Q2	Q2	Q2	Q2		
12	Cold Rolled Coil galvanized	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	
13	Cold Rolled Coil coated	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	
14	Cold Rolled Coil	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	Q1	
15	Hot Rolled galvanized	Q2	Q2								
16	Hot Rolled Narrow Strip	Q2	Q2	Q1	Q1	Q1	Q1	Q1	Q1		
17	Hot Rolled Coil	Q2	Q2	Q1	Q1	Q1	Q1	Q1	Q1		
18	Welded Tube	Q2	Q2		Q2	Q2	Q2	Q2	Q2		
19	Seamless Tube	Q2	Q2	Q2	Q2	Q2	Q2	Q2			
20	Wire Rod	Q3	Q3	Q2	Q2	Q2	Q2	Q2	Q2		
21	Reinforcing Bar	Q4	Q4								
22	Hot Rolled Bar	Q4	Q4	Q3	Q3	Q3	Q3	Q3	Q3		
23	Heavy Section	Q4	Q4								
24	Light Section	Q4	Q4								
25	Rail Section		Q4				Q3				

Steel qualities: **Q1:** < 0.18% for sum of Cu, Cr, Ni, Sn & Mo; **Q2:** 0.18% - 0.25%; **Q3:** 0.25 – 0.35%; **Q4:** > 0.35%

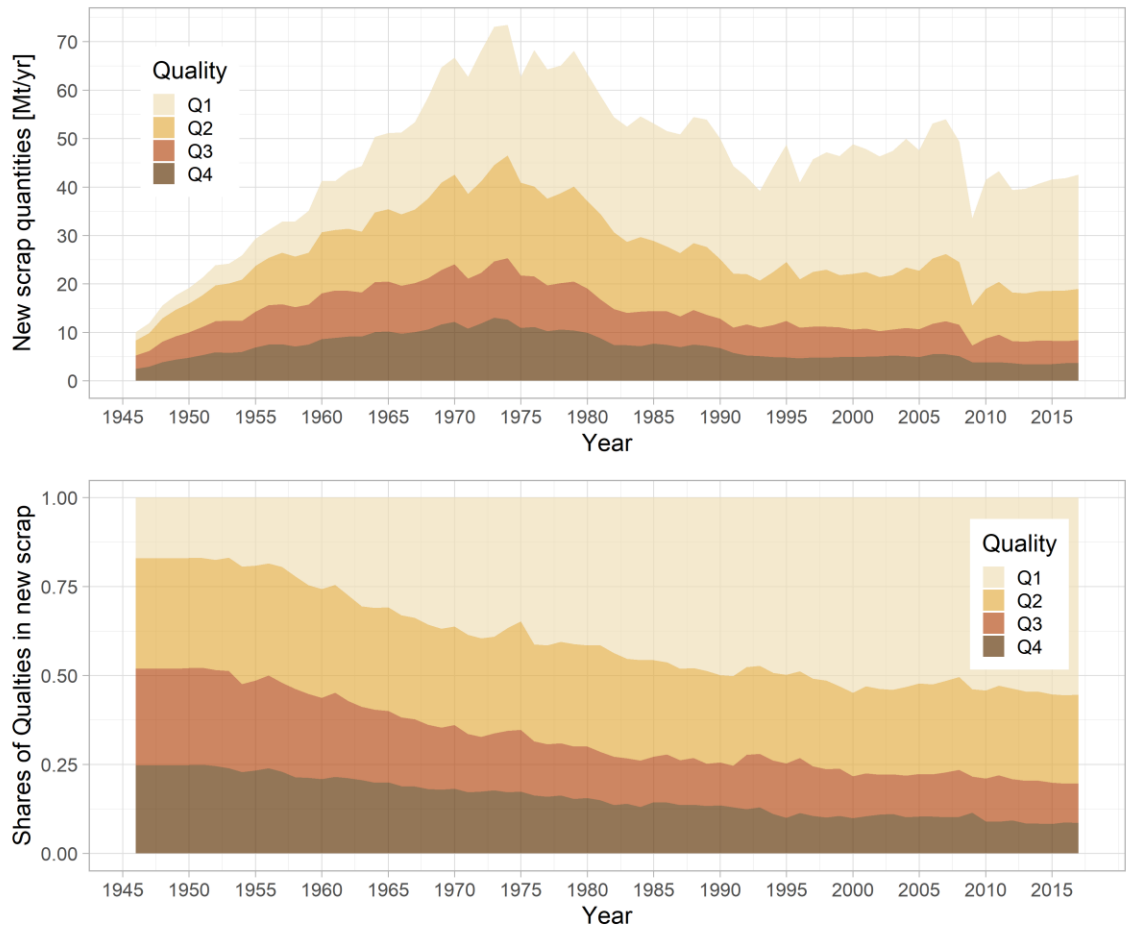


Figure E1 Absolute und relative composition of new scrap with respect to quality categories for tramp elements

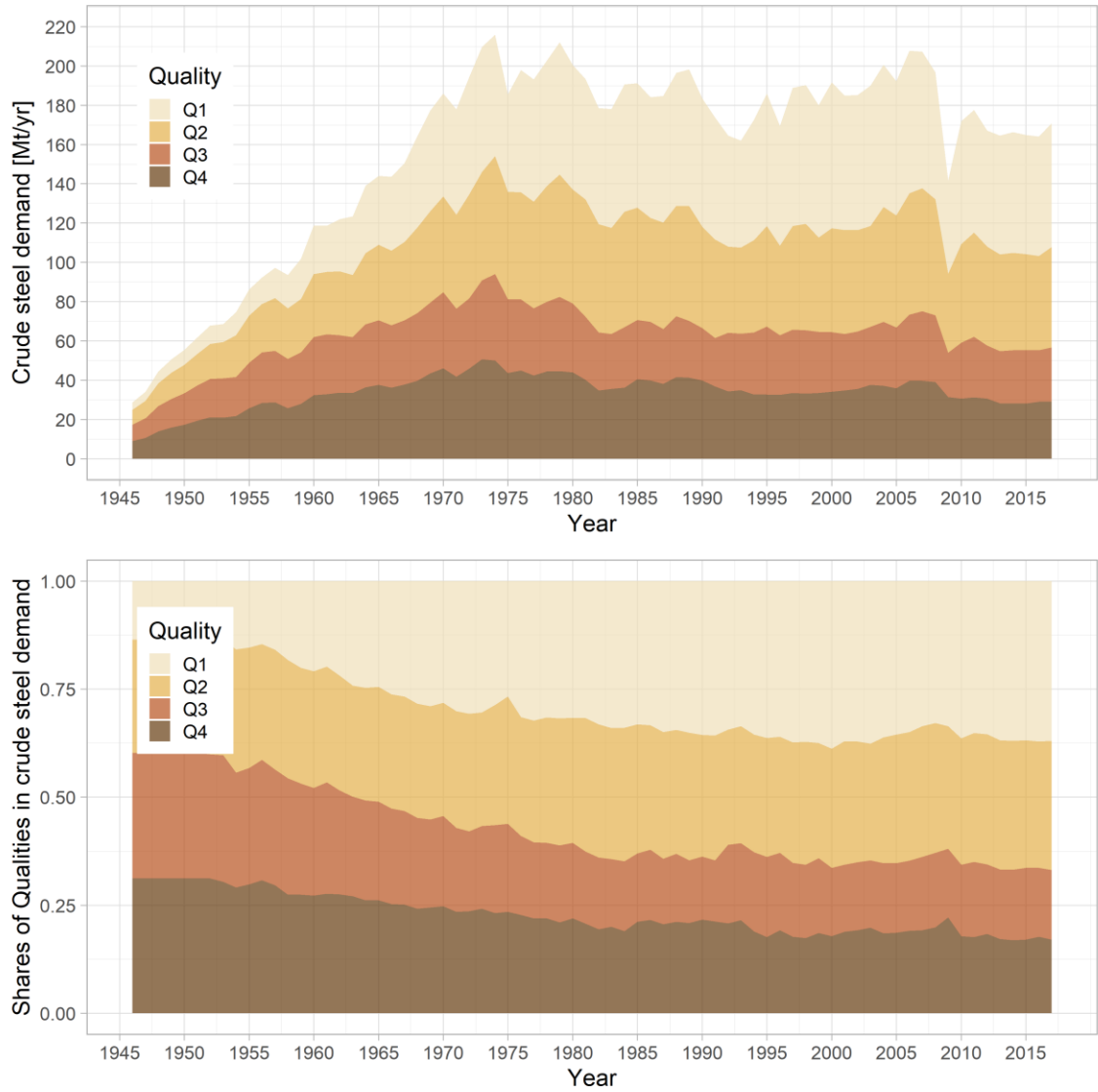


Figure E2 Absolute und relative composition of crude steel demand with respect to quality categories for tramp elements

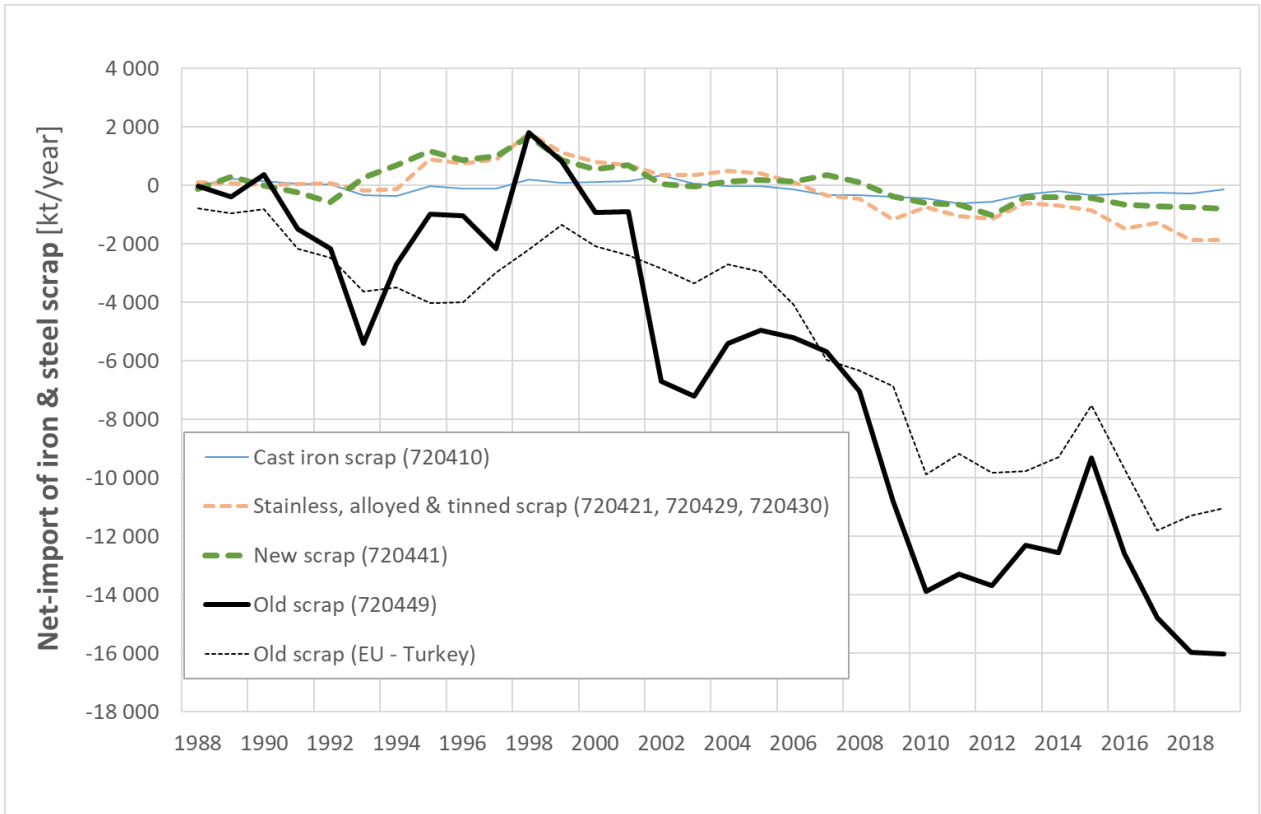


Figure E3 Net-import of iron & steel scrap into the EU-28 (data given in kt/yr) – new scrap (HS Code 720441), old scrap (HS code 720449<sup>5</sup>), cast iron scrap (HS code 720410), Stainless, alloyed & tinned scrap (HS code 720421, 720429, 720430)

<sup>5</sup> Waste and scrap of iron or steel (excluding slag, scale and other waste of the production of iron and steel; radioactive waste and scrap; fragments of pigs, blocks or other primary forms of pig iron or spiegeleisen; waste and scrap of cast iron, alloy steel or tinned iron or steel; turnings, shavings, chips, milling waste, sawdust, filings, trimmings and stampings; waste and scrap of primary cells, primary batteries and electric accumulators)

**Table E2 Calculation of excess impurities and excess purities for the tramp elements  
Cr, Sn, Cr, Ni & Mo for the European steel production in 2017**

Year 2017	Average content of impurities (Cu, Sn, Cr, Ni & Mo)	Final steel demand	Steel sources (scrap + primary iron/steel)	Cumulative <sup>1)</sup> excess scrap (see Figure 5 - paper)	Excess impurities of Cu, Sn, Cr, Ni & Mo
	%	Mt	Mt	Mt/yr	kt/yr
<i>primary iron/steel</i>	<0.05 <sup>2)</sup>		65.0		
Steel quality Q1	0.13	64.1	23.5	-65.0	<b>-52</b>
Steel quality Q2	0.21	54.3	10.6	-24.5	<b>-20</b>
Steel quality Q3	0.30	25.6	38.2	19.2	<b>17</b>
Steel quality Q4	0.40	31.0	37.6	6.6	<b>7</b>
Total		175.0	175.0		<b>-48</b>

1) *cumulative refers e.g. to the amount of Q4 + Q3 scrap in relation to Q4 + Q3 steel demand or Q4+Q3+Q2 scrap in relation to Q4+Q3+Q2 steel demand*

2) *Data provided by voestalpine AG*

## **F. Steel content in cars and trucks produced in the EU-28**

For the validation of some model results, in particular, the amount of steel ultimately ending up in cars and trucks produced in the EU-28, the data provided in spreadsheet have been used (see Table F1: Amount of steel present in cars and trucks produced in the EU-28, provided in spreadsheet).



## G. Further results – steel scrap quantities

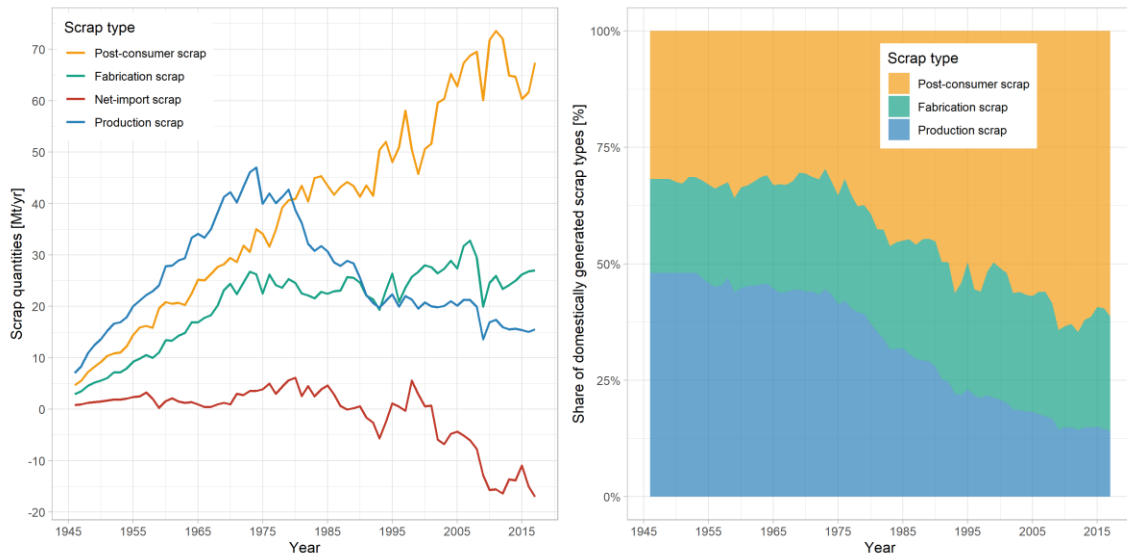


Figure G1 Annual quantities of production scrap, fabrication scrap, post-consumer scrap recovered and net-import of scrap for the EU-28 countries from 1946 to 2017 given in Mt/year (left side) and share of domestically generated production, fabrication and post-consumer scrap given in % (right side)

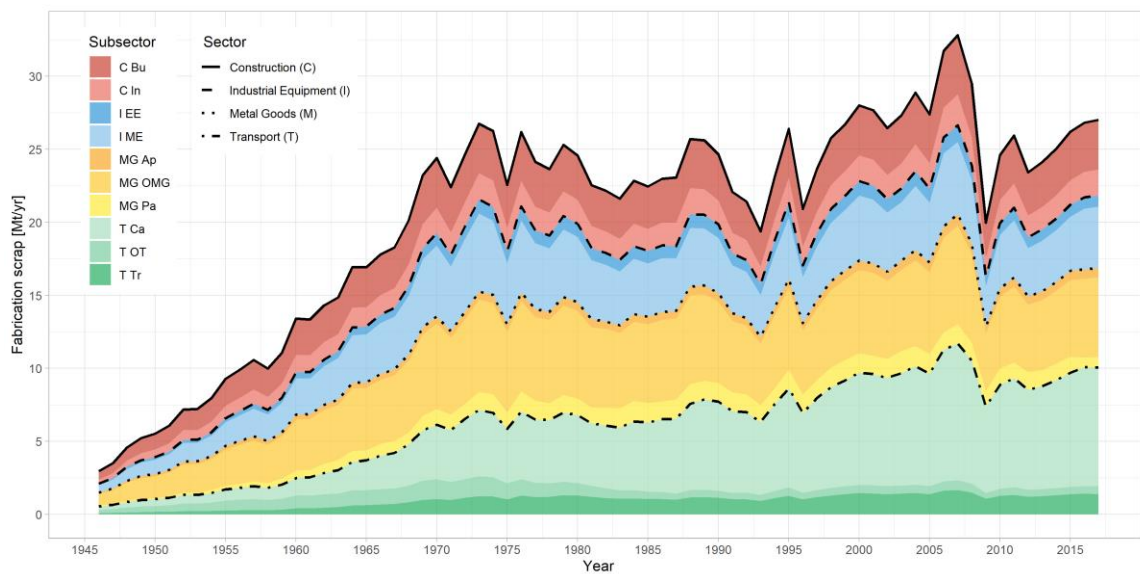


Figure G2 Annual production of fabrication scrap (given in [Mt/yr]); quantities of fabrication scrap according to the steel end-use sectors and subsectors

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