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Visualizing global trade flows of copper

An examination of copper contained in international trade flows in 2014

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# Contents

## Abstract

This Working Paper presents a brief but comprehensive graphical overview of copper contained in international trade, from copper concentrates through to finished products. Extensive data checks and a simple consolidation method were performed before visualizing the data on world maps. While data were collected and anlyzed for the period 1992–2014, the year 2014 is used here to follow the global journey of copper from mine to final users.

## Keywords

Copper, trade balances, embedded copper, foreign trade.

## Acknowledgement

# 1 Introduction

The study of metal flows in the anthroposphere helps us to better understand the impact of civilization on the environment as well as to identify areas where improvement is most needed in terms of reducing our collective footprint on the environment. In the past several years, Fraunhofer ISI has worked with the copper industry to map out stocks and flows of copper at a global and regional level in order to help guide the industry's efforts towards a more circular economy. Interim results of this effort have been the design and implementation of a comprehensive, dynamic copper flow model at a global level (Glöser et al., 2013) and the introduction of a quantitative overview of the global copper cycle and of corresponding recycling indicators to the International Copper Study Group (ICSG) World Copper Factbook (ICSG, 2013, 2014, 2015).

Strong regional differences in production, use and disposal of copper make it necessary to move from a global to a regionalized view of copper flows in order to better understand the global copper system. This move to a regionalized global copper flow model ultimately requires the creation of several regional copper flow models interacting by means of foreign trade. It is important to note that the sheer number of relevant traded commodities between all countries makes the development of regionalized models more challenging in concept and in implementation than the global model prepared initially (cf. Glöser et al., 2013).

Data on foreign trade is available from a variety of sources (e.g. UN, EUROSTAT, national customs offices) and is already used to display flows of copper in concentrates, intermediate products of copper smelting and refining as well as refined copper (cf. ICSG, 2013, 2014, 2015). However, to more fully account for copper embedded in international trade, it becomes necessary to expand the scope of commodities included in the analysis to include both semi-finished[1] and finished products. To this end, a database of relevant commodities ($\approx$ 370 6-digit Harmonised System codes, of which $>$ 300 correspond to finished products) including their estimated copper content was compiled and used in the regionalization efforts (Soulier et al., 2016). While regional flow models (cf. Soulier et al., 2016, for the EU28) use trade data for the country or region of interest vs. all other countries, it is instructive to examine the trade flows between regions in order to discern global trade patterns. In this paper, we present an overview of copper contained in foreign trade flows in 2014 between six "regions": Europe (EU28), North America, Latin America, China, Japan and the "Rest of the World".

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[1]Note that a database of international trade in semi-finished goods between selected countries can be ordered from the International Wrought Copper Council (IWCC, 2016)

# 2 Data and methods

## 2.1 Workflow and data sources

Trade data were extracted from a snapshot of the UN Comtrade Database (United Nations, 2015) taken in march 2016 (contains complete data for up to 2014) using the Harmonized System (HS) classification (version H0, see United Nations, 2002), and transferred to an in-house database including the assignment of individual trade codes to different aggregated model variables (cf. Table 1 and Glöser et al., 2013; Soulier et al., 2016) and an estimate of the copper content of each trade code as defined by Soulier et al. (2016) based on literature, interviews and own analysis.

Table 1: Summary of products included at the three stages of examination (cf. Glöser et al., 2013; Soulier et al., 2016).

| Concentrate to metal | Semi-finished products | Finished products |
|---|---|---|
| Copper concentrate | Wire (building, power, magnet, telecom. . . ) | Construction |
| Mattes & cement | Mill products (tubes, rods, bars, plates. . . ) | Consumer products |
| Blister | Castings | Industrial equipment |
| Anodes | Powder | Infrastructure |
| Cathodes | | Tansport |
| Shapes | | |

The data were aggregated to six different reporters (China, EU28, Latin America, North America, Japan, Rest of the World), each interacting with the remaining partner countries/regions. Intraregional trade (relevant for Latin America, North America, EU28 and RoW) was excluded in this work. Prior to generating global trade maps, the data were screened for errors/omissions and the necessary corrections were made by defining a multiplier for selected records in the database. Details on the editing are given in Section 2.2. The overall workflow is shown schematically in Figure 1.

## 2.2 Editing of data

Although the UN Comtrade database provides consolidated trade data, there remain a number of errors and inconsistensies in the reported figures. The types of errors identified and the procedures for editing the data are described here. In this work, we used a multiplier (correction factor) to bring the reported figures into line with what appears plausible in light of the overall magnitude of the flow and long term trends. Overall, approximately 650 records were edited in an aggregated database of $\gtrsim 37\,000$ permutations of reporter and partner countries/regions between 1992 and 2014. Note that,
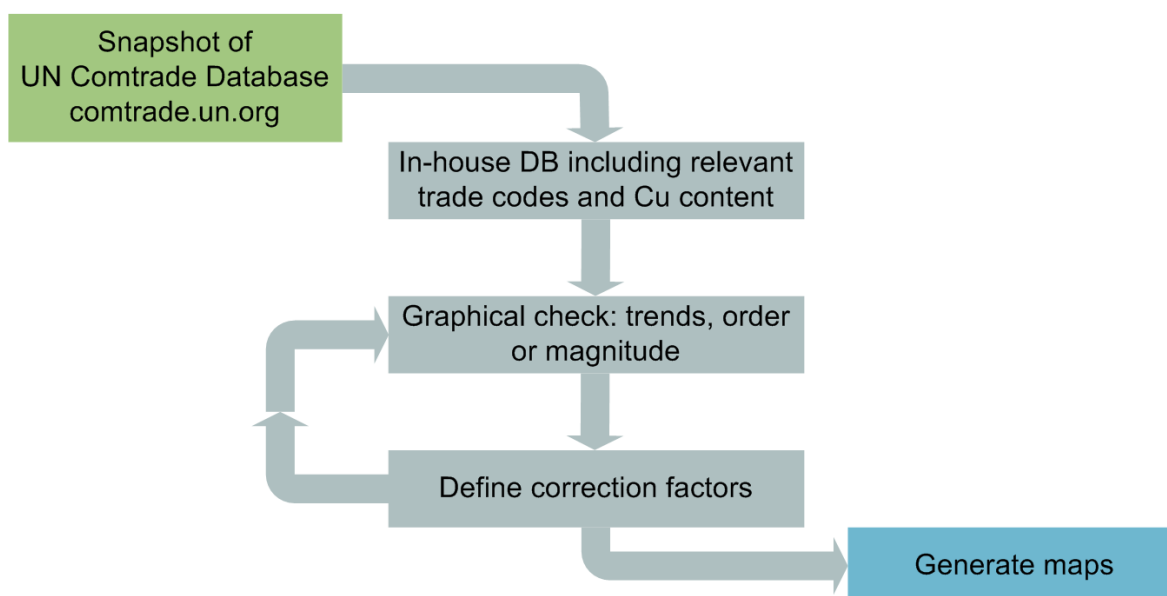
Figure 1: Steps in generating global trade maps based on published trade data.

while only data for 2014 are reported here, the historical trends are essential for assessing any given datapoint in the face of the uncertainties present.

By far the most common data error encountered are inexplicable jumps of one or several orders of magnitude. This is illustrated in Figure 2: The values reported some years for one or more trade partners (regions) are inexplicably approx. 10–1 000 times larger than expected. A likely source of these errors are different units in reporting (kg vs. 100 kg vs. metric tonnes) as well as simple typos. These were corrected by multiplying the reported figures by a multiple of 10 (0.001–0.1). This type of error also occurs in the opposite direction (values being smaller than they should plausibly be) and are corrected in the same manner (e.g. multipliers of 10..1 000).

A less common occurrence are missing values for traded net weight. These entries were added to the database in terms of net weight by using the mean value (US$ per tonne) of that commodity from adjacent years for which both net weight and dollar value were available.

## 2.3  Visualization details

Despite the editing described in Section 2.2, there remains the issue of differing reported figures between the country/region of origin and the country/region of destination. Four options present themselves to reconcile the figures:

1. Reconcile each record in the database based on knowledge of the possible sources of error or reporting practices. While desirable, this approach is impractical for a database of close to
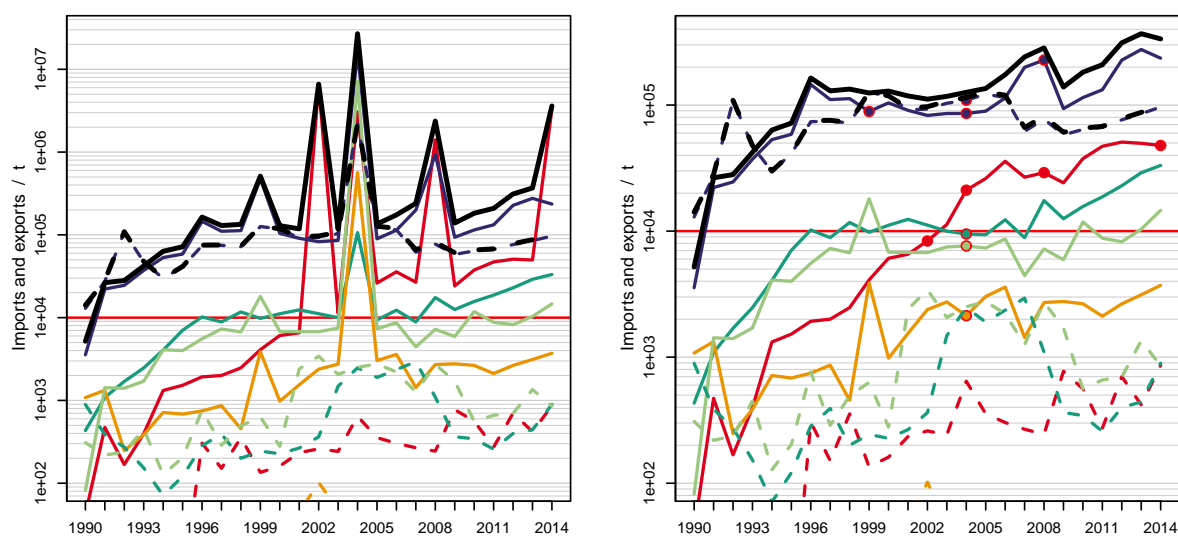
Figure 2: Example of the graphical data check and editing procedure using actual trade data for one region vs. all others: (left) original trade data; (right) edited trade figures, each edited data point marked by a small red circle. Solid lines represent imports, dashed lines exports; the thick solid line is the sum of imports from all regions and the thick dashed line the sum of exports to all regions; different colors are for different trading partners (regions). Notice the logarithmic scaling and the different vertical ranges; the horizontal red line is set at 10 kt contained copper in both graphs.

500 000 entries corresponding to yearly import and export flows between regions for each HS code considered.

2. Give precedence to one of the countries/region. This is the approach followed e.g. by Soulier et al. (2016) when creating regional models. However, this approach appears inappropriate for the work at hand (visualizing global trade flows between regions) where there is no grounds for giving precedence to one reporter over another.

3. Trust either import flows or export flows only. There are grounds to suspect that export data should be better reported than import data, thus suggesting the use of export data only and ignoring the differences between reporters. However, this suspicion has not been actually tested to our knowledge.

4. For each flow, take the average of the reported values from both countries/regions. In effect, this apporach accepts that the numbers are uncertain to varying degrees and declines to make a weighting or decision on precedence, thereby accepting both values as equally "right" or "wrong". This approach, sketched in Figure 3, is followed below.

With the figures consolidated as described above, we proceeded to visualize trade flows on world maps. In order to ensure comparability between the maps, the following features are common to all visualizations (see Figure 4 on page 9):

**Data from comtrade**

| | | |
|---|---|---|
| **Country/Region A** | | **Country/Region B** |
| Reports export of 210 kt (Cu content) | Mean of reported flows 200 kt (Cu content) | Reports import of 190 kt (Cu content) |
| Reports import of 55 kt (Cu content) | Mean of reported flows 70 kt (Cu content) | Reports export of 85 kt (Cu content) |

Difference of mean reported flows

**Depiction**

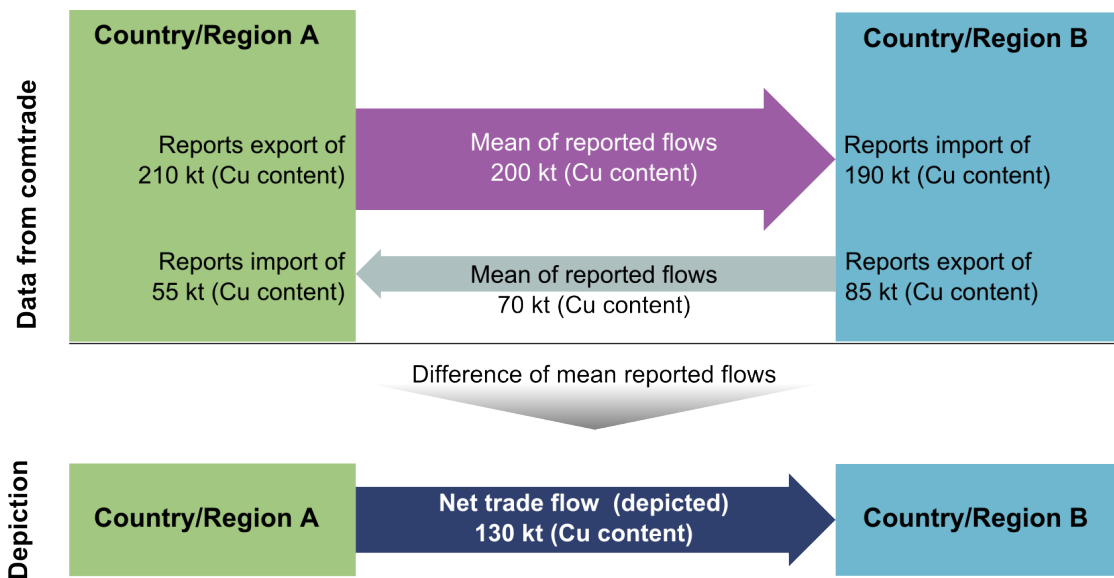| | | |
|---|---|---|
| **Country/Region A** | Net trade flow (depicted) 130 kt (Cu content) | **Country/Region B** |

Figure 3: Sketch of the procedure used to consolidate reported data for use in the visualizations below.

- Trade arrows depict net trade flows computed as shown in Figure 3

- All figures are rounded to the nearest 10 kt

- A threshold of 10 or 100 kt has been applied to each map in order to highlight major flows in each category/variable. Which threshold is used is shown at the bottom left of each map

- The thickness of the arrows scales linearly with the magnitude of trade and is independent of the selected threshold; i.e. arrow thickness *can* be directly compared between maps.
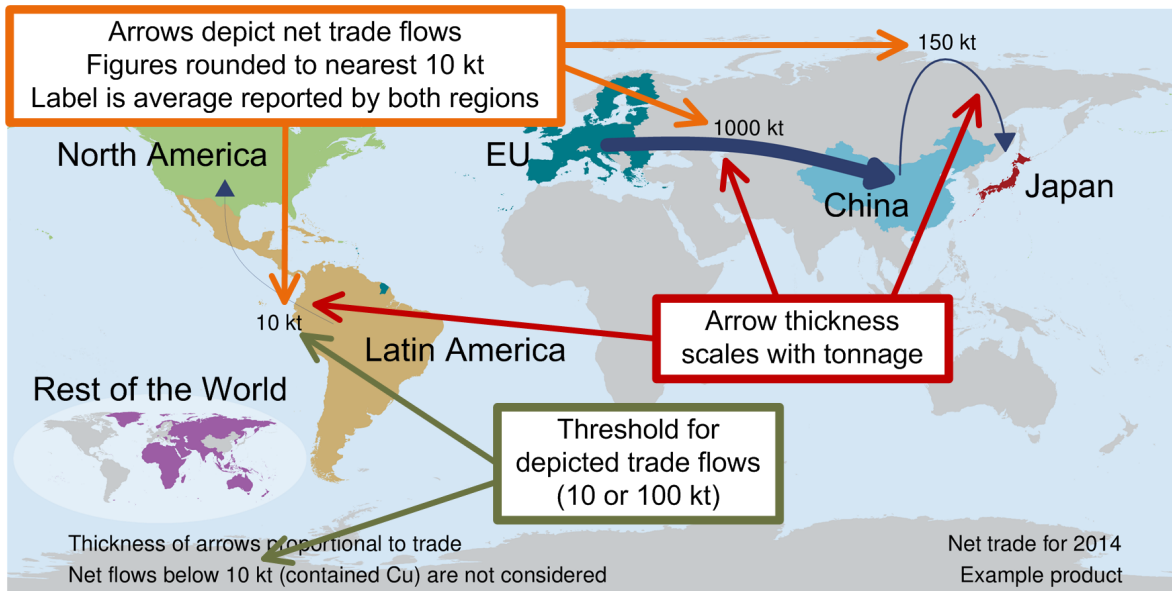
Figure 4: Example global trade map for copper flows highlighting the common features to all visualizations.

# 3 Global trade in copper concentrate, metal and semi-finished goods

## 3.1 Trade in concentrates

Key data for copper traded as copper concentrates is visually reported by ICSG in their annual World Copper Factbook (e.g. ICSG, 2015). Figure 5 reports similar data but projected onto the regions relevant to this work. Inspection of Figure 5 reveals Latin America to be by far the largest exporter of copper concentrates worldwide (altogether $\approx 3.3$ million tonnes of contained copper), with China being the main destination for copper concentrates from Latin America ($\approx 1\,400$ kt), followed by Japan and Europe (close to 700 kt each). Significant quantities are also exported from the Rest of the World ($\approx 1.1$ million tonnes net exports), with the largest export destination being China ($\approx 1.2$ million tonnes). While North America is also a net exporter of copper concentrates, the amounts are comparatively small ($\approx 500$ kt overall in 2014).[1]
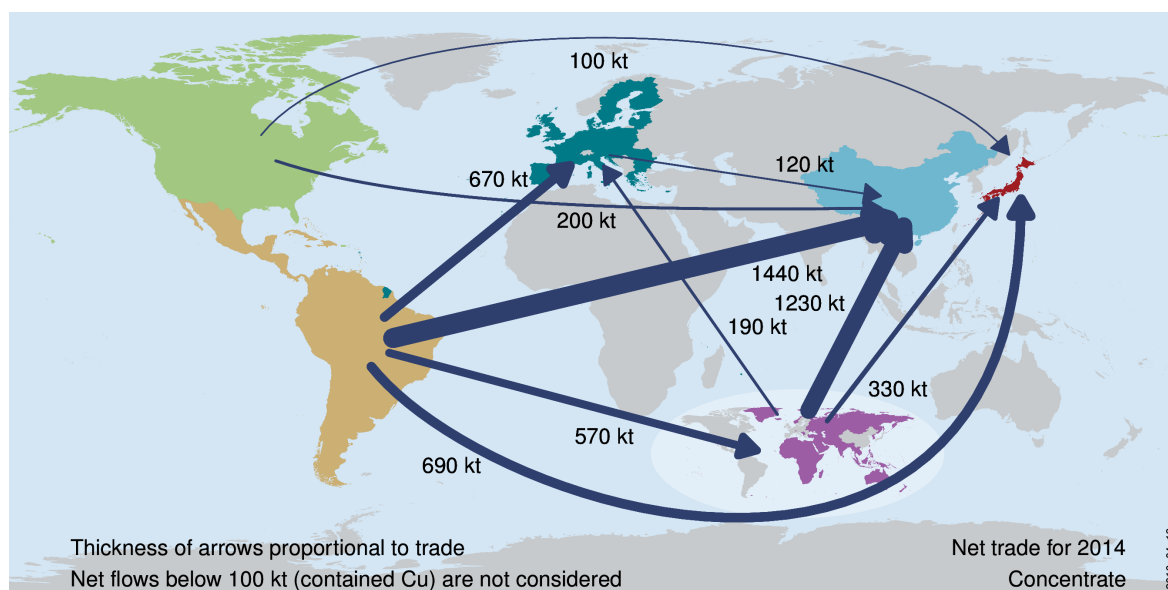


Figure 5: Trade in copper concentrates.

Adding up the estimated net export figures shown in Figure 5 we arrive at the following summary picture:

- Latin America, the Rest of the World and North America, in that order, appear to be the suppliers of copper concentrates for the world. However, the sum of all inter-regional trade flows in Figure 5

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[1]The difference between this and the net flows reported in Figure 5 arises from net exports from North America to the EU, Latin America and the Rest of the World which collectively amount to $\approx 200$ kt but are each smaller than the depiction threshold of 100 kt.

is below 6 000 kt of contained copper.With a world mine production of over 18 000 kt of contained copper in 2014, this figure is only modest, indicating that over ⅔ of copper concentrates are processed in their region of origin ("region" as defined above and shown in Figure 4).

- By far the largest destination for exported copper concentrates is China, accounting for over 60% of all net trade flows shown in Figure 5. Both Japan and Europe are also important net importers of copper, with cummulated net imports of close to 1 100 kt and 800 kt of copper contained in concentrates, respectively.

## 3.2  Trade in copper metal

As for copper concentrates, key data for refined copper traded internationally is visually reported by ICSG in their annual World Copper Factbook (e.g.  ICSG, 2015). Figure 6 reports similar data for copper metal (summation of copper contained in products ranging from "blister" to "shapes") but projected onto the regions relevant to this work.
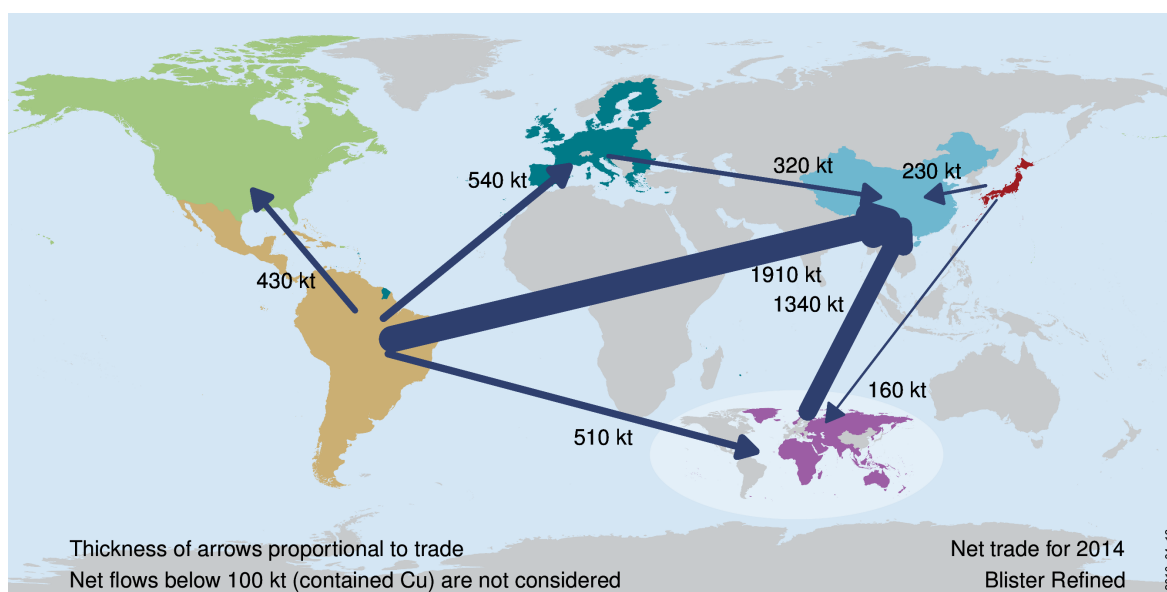


Figure 6: Trade in copper metal (blister, anodes, cathodes, shapes; includes unwrought alloys).

The picture that emerges from Figure 6 is very similar to that for copper concentrate trade:

- Latin America ($\gtrsim$ 3 500 kt, representing $\gtrsim$ 60% of all trade flows depicted in Figure 6) followed by the Rest of the World ($\approx$ 1 300 kt net exports to China but overall only $\approx$ 700 kt because of imports from Latin America and Japan) are the undisputed sources of copper metal for the world.

- China remains the main destination for copper at this stage of the value chain, followed distantly by North America and the EU. China imports a total of $\approx 3\,900$ kt of copper metal from each and every other region of the world as defined in Figure 4. This corresponds to $\approx 70\%$ of all trade flows shown in Figure 6 and $\approx 85\%$ of all net imports (taking one region vs. all others). North America is a distant second in copper metal imports, buying $\gtrsim 400$ kt from Latin America. This contrasts with the case of concentrates, where North America is a (minor) net exporter. Net imports for the EU at this stage are below 300 kt.

- In contrast to the case for concentrates, Japan is a net exporter of copper metal.

Taken together with concentrates, close to 11 million tonnes of copper (concentrate + metal) were traded internationally[2] in 2014 between the regions defined in Figure 4. Of those 11 million tonnes, close to 7 million tonnes went into China ($\approx 60\%$ of trade as depicted in Figures 5 and 6).

The overall amount of copper traded between the world regions as copper semi-finished products is much smaller, as shown in Figure 7. Overall, the depicted trade flows add up to less than 800 kt. This speaks for strongly regional markets for copper semis, with the production of semi-fabricates being in comparatively close proximity to the manufacturing centers using those semi-fabricates to produce end-use products. Also the trade pattern is different from that for concentrates and metal. At this stage of the supply chain, Europe emerges as the largest net exporter worldwide with $\approx 300$ kt ($\gtrsim 40\%$ of the trade depicted in Figure 7), followed by Japan with $\gtrsim 100$ kt. The Rest of the World and Latin America are both net importers of copper semis (approx. 200–300 kt each), as is China with around 100 kt net imports. The trade balance for copper semis for North America is essentially balanced.

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[2]Please note that this refers to the *net* trade flows shown in Figures 5 and 6. The total amount of copper traded is larger if imports and exports are accounted separately, or if intra-regional trade (e.g. trade between EU Member States of the European Union) would also be accounted separately.
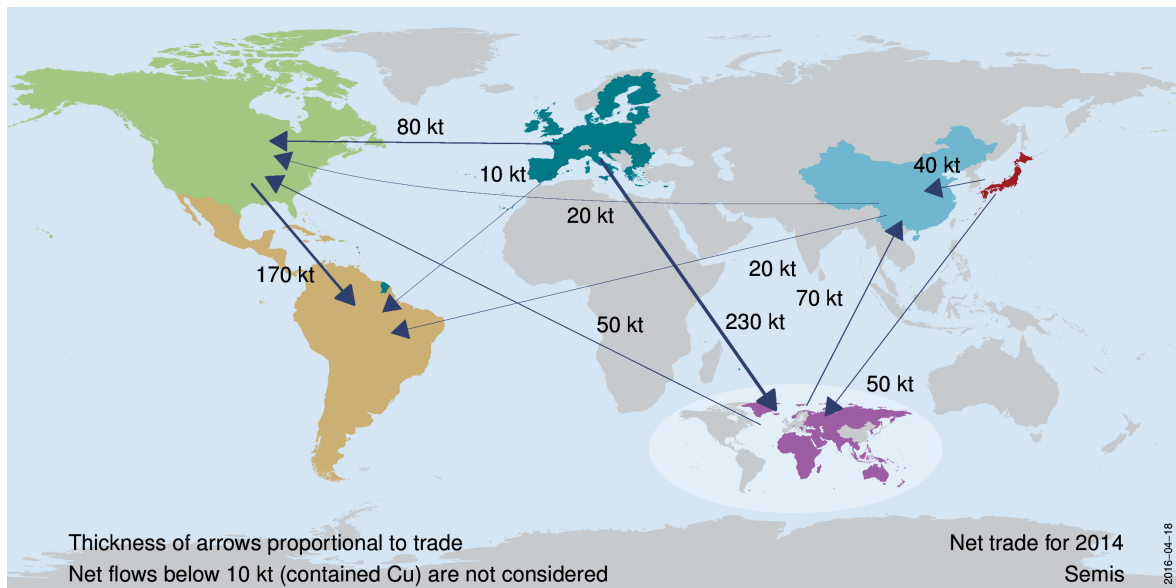
Figure 7: Trade in copper semi-finished products.

# 4 Global copper flows contained in finished products

The trade pattern observed for copper concentrates and copper metal is reversed when considering finished products. Here, China emerges as the largest exporter of embedded copper, having more exports than imports to all regions considered in this analysis. Altogether, China had net exports amounting to approx. 2.8 million tonnes of contained copper in finished products. The largest importer was the region Rest of the World, with net imports of close to 1.4 million tonnes of contained copper. China also exported $\approx$ 500–650 kt of contained copper to Europe and North America. However, Europe also had net exports towards the Rest of the World, North America and Latin America (altogether $\lesssim$ 400 kt contained copper), so that its trade balance is only $\lesssim$ 200 kt net imports.[1] In contrast, North America had net imports from all other regions[2] in addition to its net imports from China, for a total of around 1.1 Million tonnes of contained copper. Latin America, the undisputed top exporter for copper concentrates and metal is a net importer of copper in finished goods ($\lesssim$ 250 kt contained copper).[3] Altogether, $\approx$ 3.7 million tonnes are contained in the *net* trade of finished goods among all regions.
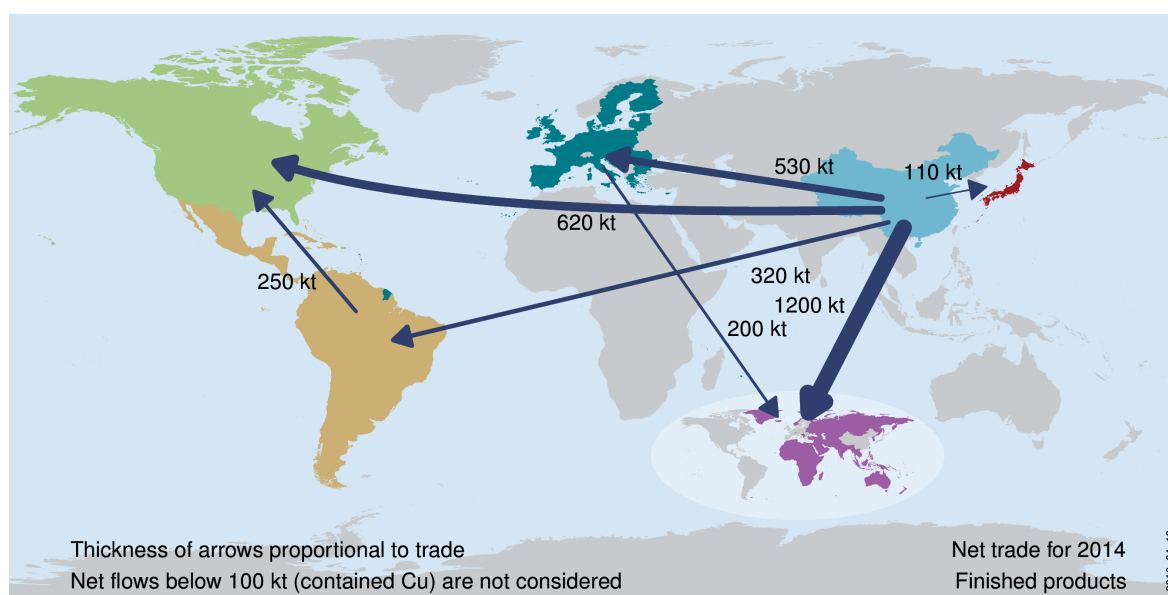


Figure 8: Overall trade of copper in end-use products

Figures 9 and 11–14 show the trade flows from Figure 8, disaggregated into five end-use categories: building construction, consumer products, industrial uses, infrastructure and transport. Of these, the

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[1]Net exports from the EU to North and Latin America amounting to $\approx$ 180 kt are not shown in Figure 8 because they each fall below the depiction threshold of 100 kt.

[2]Imports from the EU, Japan and the RoW are not depicted in Figure 8 because they are < 100 kt each but collectively amount to $\approx$ 260 kt .

[3]Net imports from the EU, Japan and the Rest of the World are not depicted in Figure 8 because they fall below the threshold of 100 kt. They collectively amount to $\approx$ 170 kt.

most significant quantities of copper are contained in consumer products (Figure 9). Lowering the visualization threshold from 100 kt (used for concentrates, metal and finished products) to 10 kt (used for semi-finished products) reveals the complex network of interregional trade with products ranging from kitchenware to large home appliances. As for the aggregated picture, China is the largest source of exported consumer products ($\approx$ 1.7 million tonnes), and in fact the only region analyzed here that only exhibits net exports. The Rest of the World and North America are the largest net importers of copper in consumer products, with approx. 600 kt and 500 kt, respectively. Note that the trade balance of North America vs. all other regions is negative. The EU, Latin America and Japan collectively have net imports of only around 500 kt (including imports from each other). Japan has net exports of consumer products to all regions except China but all figures are < 10 kt contained copper and thus not depicted in Figure 9.
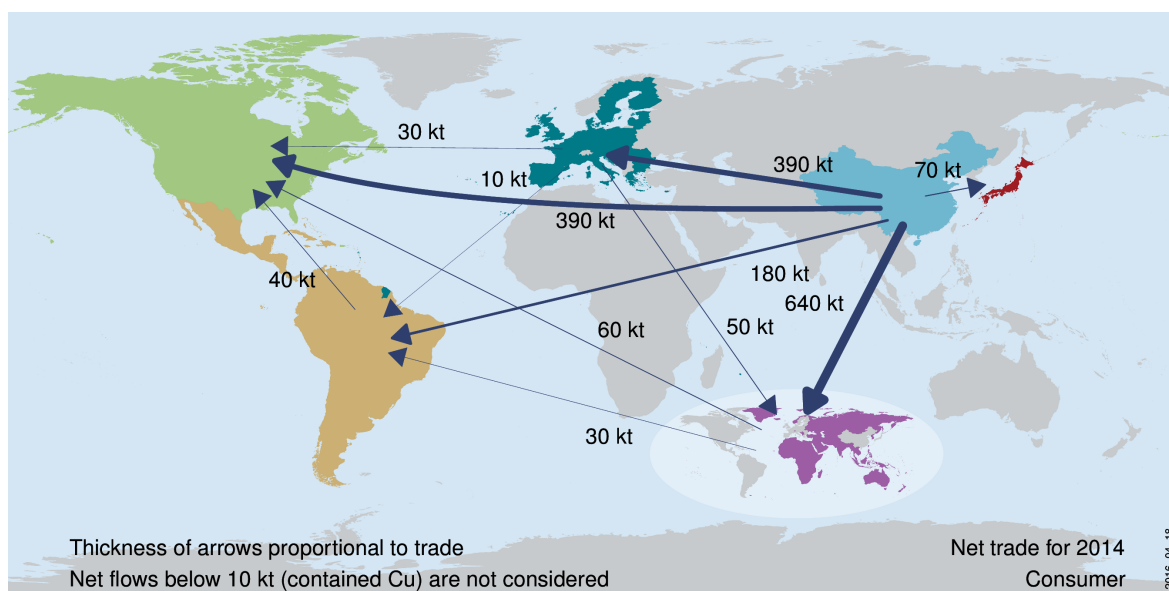


Figure 9: Trade of copper embedded in consumer products.

# 5 Summary and conclusions

With the information shown above for concentrates, metal and semi-finished goods, it is possible to derive the relative positions of each of the regions regarding the global copper supply chain from mining through to finished products. These are summarized in Table 1 and Figure 10. Together, they provide an overview of the role each region plays in a very roughly defined global copper supply chain.

Table 1: Summary of traded copper along the supply chain up to finished products. All figures rounded to the nearest 50 kt. $\sum$ each column $= 0 \pm 50$ kt (rounding).

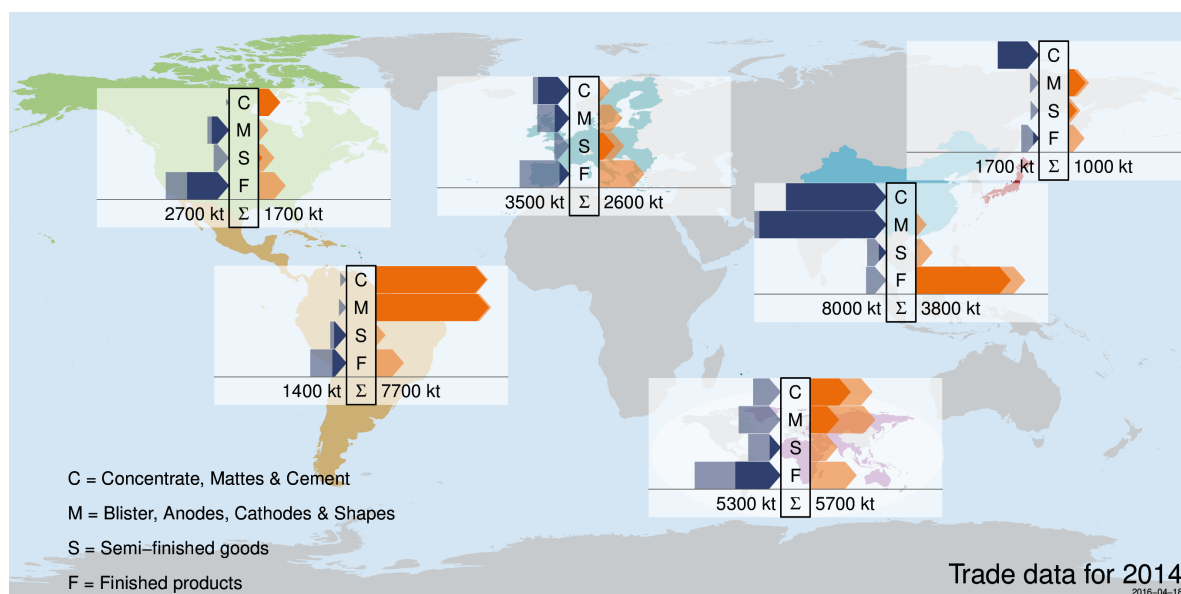| Region | Net Imports | | | | Sum |
| --- | --- | --- | --- | --- | --- |
| | Concentrate | Metal | Semis | Finished | |
| China | 3000 kt | 3850 kt | 50 kt | -2800 kt | 4150 kt |
| Europe (EU28) | 850 kt | 300 kt | -300 kt | 200 kt | 950 kt |
| Japan | 1150 kt | -350 kt | -100 kt | 50 kt | 700 kt |
| Latin America | -3350 kt | -3400 kt | 200 kt | 250 kt | -6300 kt |
| North America | -500 kt | 350 kt | 0 kt | 1150 kt | 1000 kt |
| Rest of the World | -1100 kt | -750 kt | 150 kt | 1200 kt | -500 kt |



Figure 10: Graphical summary of internationally traded copper at different stages between concentrate and finished products. Arrows with transparency/of lighter color depict imports and exports; net flows are depicted with solid colors/without transparency. The sums shown are for all imports and all exports, not for the net flows.

Simplistically speaking, copper comes from Latin America and the Rest of the World and goes as concentrate or metal mostly to China, where it is transformed to finished products. Significant amounts of copper are exported back from China to all other regions analyzed here in the form of finished

products. The tonnage of copper in international trade in semi-finished products is modest compared to concentrate, metal and finished products, pointing to strong regional markets.

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# A  Additional trade maps for finished products

Trade in finished products was composed of roughly five categories: building construction (Figure 11), consumer products (Figure 9 on page 15), industrial uses (Figure 12), infrastructure (Figure 13) and transport (Figure 14). The largest amounts of copper contained in finished products are traded in the general category "consumer products" and discussed in the main text. Significant amounts are also traded in the general category "building construction". The amounts traded in the categories "industrial uses", "infrastructure" and "transport" are minor, suggesting strong regional markets for these goods. The exception are exports in the category "transport" from Latin America to North America. This flow is dominated by code HS 854430 (Ignition/other wiring sets for vehicles/aircraft/ship) mainly from Mexico.
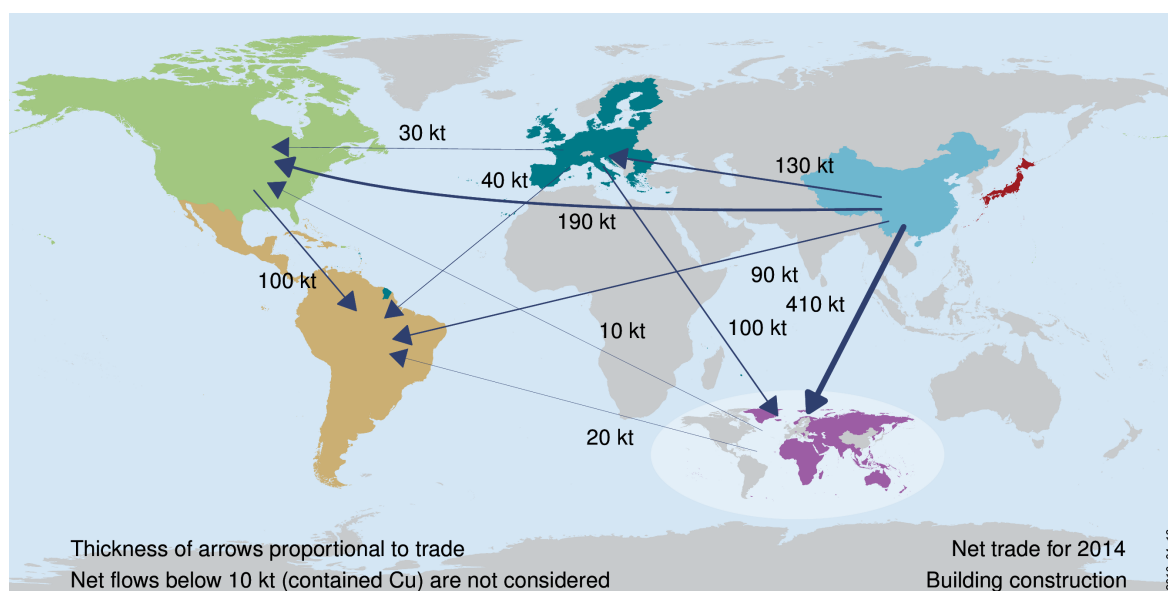


Figure 11: Trade of copper embedded in products for building construction (including water distribution, heating, gas, roofing, decoration, power and telecom wiring).
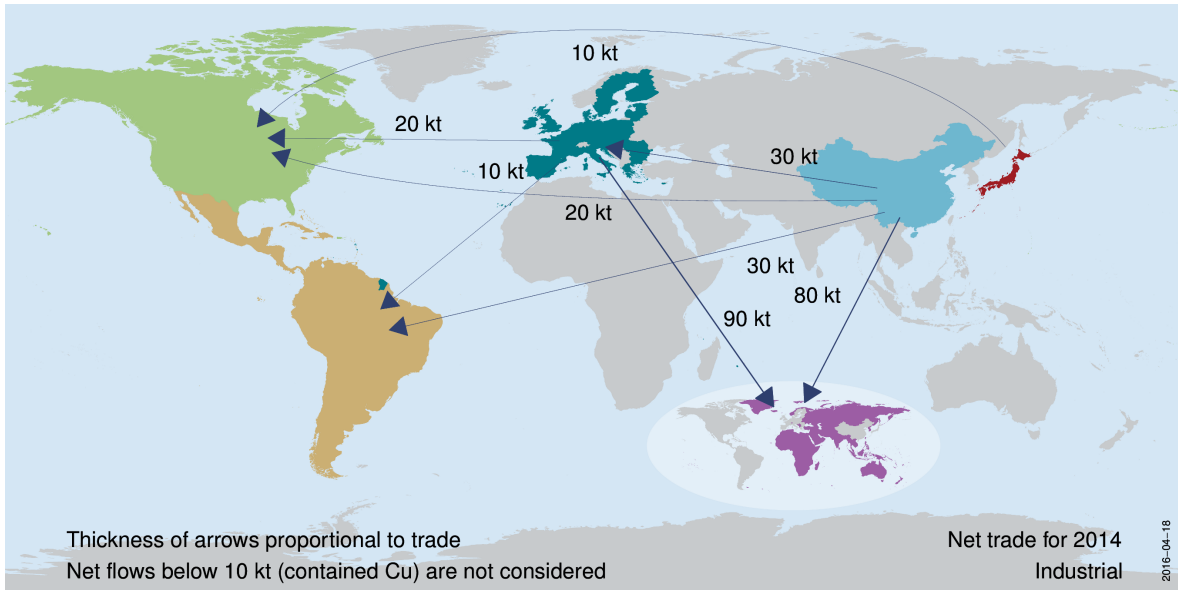
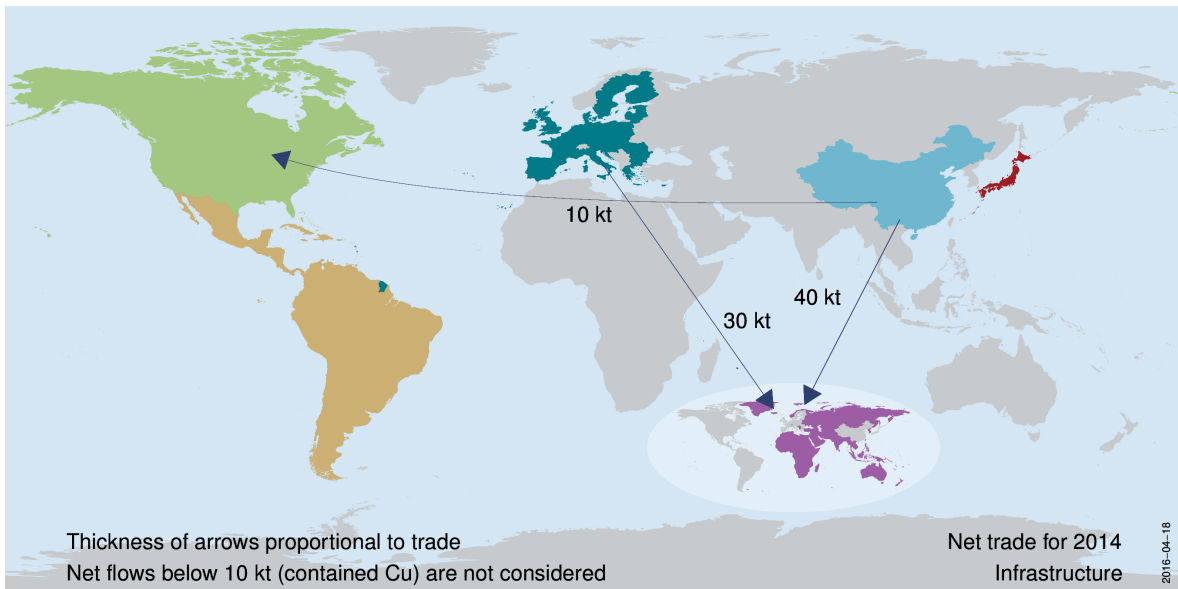Figure 12: Trade of copper embedded in products for industrial use.



Figure 13: Trade of copper embedded in infrastructure-related products (power transmission and distribution, telecommunication networks).
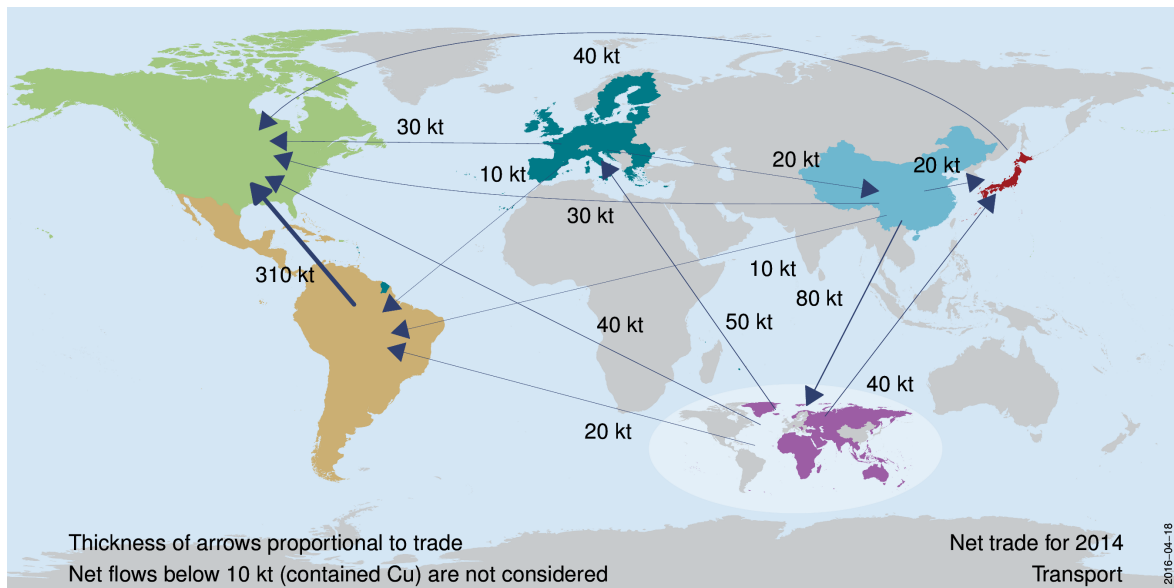
Figure 14: Trade of copper embedded in transport applications (automotive, ships, aerospace).

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