Global Substitution Indicators

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Competitive Information: Competitors should not discuss the market share of a particular copper producer or copper fabricator’s products. Furthermore, nothing should be said at a meeting which could be interpreted as suggesting prearranged market shares for such products or producer production levels. The overall market share of copper products may be discussed with regard to competition with non-copper products and general market acceptance.

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The Role of Legal Counsel: Legal counsel attends association meetings to advise association staff and other meeting attendees regarding the antitrust laws and to see that none of the matters discussed or materials distributed raise even the appearance of antitrust improprieties. During the course of a meeting, if counsel believes that the discussion is turning to a sensitive or inappropriate subject, counsel will express that belief and request that the attendees return the discussion to a less sensitive area.

A paper entitled ‘Copper Industry Trade Associations and Antitrust Laws’ is available upon request.

10/92, 5/93, 10/10

1. Other foreign competition laws apply to International Copper Association, Ltd. (ICA)’s activities worldwide.

¹ Other foreign competition laws apply to International Copper Association, Ltd. (ICA)’s activities worldwide.
Summary

- In 2018, substitution remained relatively low.
- As an aggregated impact of substitution loss and gain, net substitution has increased by 7.6%, but stayed relatively stable at 0.8% of the copper use in 2018.
- ‘Loss’ to miniaturization has declined by 16.9% and the total loss (substitution and miniaturization) stands at 1.2% of the copper use in 2018.
- Over the next five years, a very gradual increase of substitution and miniaturization is expected.
- In the current cost environment, substitution is stronger where alternative materials offer performance advantages and lower price, and where the material costs are a larger % share of the total costs.
- Key factors impacting substitution are relative material costs, copper price volatility, relative material weight, regulations/standards and new technologies.
- Energy efficiency standards have a strong positive impact on the preference for copper in electrical applications where aluminum generally underperforms.
- Building, electric and fire standards also continue to favour the use of copper in wiring.
- Miniaturization is ongoing, mainly driven by redesign cycles and new technologies. However, copper based miniaturization solutions generally offer a strong defence against substitution.
- China, the largest copper use region, has a preference for copper in electrical applications as it focuses on trusted materials delivering quality.
- Electrification, higher energy efficiency requirements and e-mobility hold large growth opportunities for copper over the next few years.
Examples of Companies Interviewed

<table>
<thead>
<tr>
<th>Fabricators: 29</th>
<th>OEMs: 14</th>
<th>End users, trade associations, experts: 19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurubis</td>
<td>LEONI</td>
<td>COPEL</td>
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<td>Nexans</td>
<td>Schneider Electric</td>
<td>Midea</td>
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<td>SIEMENS</td>
<td>elica</td>
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<td>Parker</td>
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<td>Prysmian Group</td>
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<td>KME</td>
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<td>APPLiA</td>
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<td>Plettenberg</td>
<td>PRECISION TUBE</td>
<td>Home Appliance Europe</td>
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<td>Rheinmetall</td>
<td>Automotive</td>
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## Core Measures of Substitution and Miniaturization

<table>
<thead>
<tr>
<th>Expression</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>Copper use</td>
<td><strong>Copper Use 2018</strong> is the copper volume used in an application in 2018.</td>
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<tr>
<td>- Substitution Loss</td>
<td>Potential copper use lost in the application as copper was substituted by competing materials e.g. aluminum, plastics.</td>
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<tr>
<td>+ Substitution Gain</td>
<td>Based on certain factors, such as regulation, copper gained market share and copper use against competing materials.</td>
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<tr>
<td>= Net Substitution</td>
<td>The sum of the Substitution Loss and Gain is <strong>Net Substitution in 2018</strong>.</td>
</tr>
<tr>
<td>Net Substitution as a % of Copper Use</td>
<td>Products are becoming smaller and more efficient, reducing the volume of copper used. Copper is still used in the application.</td>
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<tr>
<td>Net Substitution - Loss to Miniaturization</td>
<td>The sum of the Net Substitution and the Loss to Miniaturization is the <strong>Total Loss in 2018</strong>.</td>
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<tr>
<td>= Total Loss</td>
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<tr>
<td>Total Loss as a % of Copper Use.</td>
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</table>
In 2018, Substitution and miniaturization Loss Remained Low at 1.2% of Global Use

Substitution loss and miniaturization have declined in 2018 mainly due to the stable relative costs, as at this level OEMs and manufacturers are not motivated to increase substitution.

Interview quotes: “There is not enough motivation to change copper to aluminum at these prices, however, more cost pressure will (likely) change the view.”

“Miniaturization is mainly technology-driven and difficult to prevent.”
Total Loss has Declined for Many Copper Products

Total Loss (Substitution and Miniaturization) by Copper Products 2009–2018 in kt

- Low Voltage Energy Cables
- RBS, Bare Wires
- Telecom Data Cables
- Power Cables
- Cu Alloy PSSF
- Copper Tube
- Winding Wires
- Other Products

Total Loss has Declined for Many Copper Products

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Substitution Expected to Stabilize Before Gradually Increasing

Substitution Loss, Gain and the Loss to Miniaturization 2018 in kt and % of Copper Use

- Substitution Loss
- Substitution Gain
- Loss to Miniaturization
- Net Substitution as % of Copper Use
- Total Loss (Substitution and Miniaturization) as % of Copper Use

Interview Quote: “Energy transition holds huge opportunities for copper but may also lead to an increase in substitution and miniaturization.”

- Electrification and e-mobility will increase demand for electrical applications, driving copper prices higher and possibly increasing substitution.
- New technologies will continue miniaturization.
Distribution of Net Material Substitution by Copper Products 2018 (% of Total)

- Copper Tubes: 10%
- Telecom Data cables: 14%
- Power Cables: 15%
- Winding Wires: 26%
- Alloy and Other Products: 8%
- Bare Cu Wire, RBS: 2%
- Low Voltage Energy cables: 7%

Total: 242kt

Net Material Substitution by products 2017–2018 in kt

- Copper Tube: -18.5
- Cu/Alloy PSSFs: -4.8
- RBS, Bare Wire: -2.6
- Low Voltage Energy cables: -2.6
- Power Cables: -25.0
- Telecom Data Cables: -25.0
- Winding Wire: -35.5
- Alloy and Other Products: -42.0

Total: 225kt  Total: 242kt
Substitution and Miniaturization Occur Across the Market

Comparison of Copper Use, Net Substitution and Loss to Miniaturization by Copper Products in 2018 (% of Total)

Interview Quote: “Miniaturization is a good remedy against substitution. Copper is the better material for many applications and if new copper-based technologies allow miniaturization, there is no strong need for substitution.”

* Forecast
China Contributes Most to Substitution and Miniaturization in Absolute Terms but Least as a % of Use

Distribution of Substitution Loss, Gain and Loss to Miniaturization to Geographic Regions 2018 (in kt and % of Total)

China’s Net Substitution as % of Copper Use is at 0.6%. This is lower than in other regions.

Regions with strong cost pressure will have higher % Net Substitution on Copper Use.
China’s Preference for Copper is Driven by Focus on Quality and Tradition

Regional Substitution Factors in China

- China’s approach to substitution is not only dominated by drivers usual in other regions. Factors such as social responsibility and long investment horizon play a key role in substitution decisions, especially for state-owned utilities.

- Tradition strongly impacts material decisions in China, with a high threshold for substituting copper, the trusted and proven material.

- The relatively tight structure of urban areas in China also creates a preference for copper in electric wiring and cabling.

- In the Chinese A/C market, the widely used dual heating and cooling units restrict substitution of copper HEX tubes.

- Expected cost pressure in the coming years will reduce Chinese manufacturers’ and OEMs’ preference for copper. At the same time, tradition, quality requirements and a focus on reducing failure risks will restrict copper substitution in China.
Material Alternatives

Net Substitution by Materials as % of Total Substitution

Interview Quotes:

"Copper is better than aluminum for electric and thermal conductivity, but aluminum-based technologies are (attempting) to close the performance gap."

"New materials bring new improved technologies."

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Factors and Influences 1

<table>
<thead>
<tr>
<th>Factors influencing material decisions</th>
<th>Relative material costs</th>
<th>Relative weight</th>
<th>Relative Footprint</th>
<th>Relative Material Flexibility</th>
<th>Relative Material Strength</th>
<th>Relative Conductivity</th>
<th>Technology/Connectivity with Other Systems</th>
<th>Regulatory pressure</th>
<th>Pressure from OEMs/end users</th>
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Main drivers or constraining factors of substitution and miniaturization:

- **Building wires:** building regulations.
- **Automotive Wires:** fuel efficiency and the related relative weight, footprint and flexibility of the material.
- **Power Cables:** relative costs, electric conductivity and cost pressure from utilities.
- **Telecom/Data Cables:** technology change.
- **Winding wires:** relative costs, energy efficiency regulations, new electric motor types, strength, flexibility of the material.

Interview Quotes: “Fuel efficiency objectives put extreme pressure on automotive manufacturers to reduce weight. Reducing weight is sometimes even more important than saving costs.”

“If technology improvements bring material reduction and improved performance, there is no need to substitute copper with aluminum.”
Factors and Influences 2

<table>
<thead>
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<tr>
<td>Bare Cu Wire &amp; RBS</td>
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**Color code:**
- Very important
- Important
- Relevant
- Applicable
- Not relevant

**Main drivers or inhibitors of substitution and miniaturization**

- **RBS/Bare Wire:** relative costs, connecting technology in busbars
- **Cu/Alloy PSSF:** Relative conductivity, flexibility and strength of the materials
- **Plumbing Tube:** technology change to PEX (plastics). Relative costs and pressure from construction companies/plumbers
- **Industrial Copper Tube:** relative costs, weight, footprint, aluminum microchannel technology
- **Alloys and Other Products:** relative costs, safety and health regulations and strength of the material

**Interview Quotes:** “Efficiency, functionality and price have been the key considerations for material selection for a Chinese motor producer.”
Correlation With the Copper-Aluminum Price Ratio

Price Ratios (Cu-Al, Cu-SS304) and Net Substitution in kt

- **Strong correlation coefficient** copper / aluminum price ratio and Net Substitution 2010–18: +0.8

**Price Ratio**
- Copper-
  Aluminium

**Price Ratio**
- Copper -
  Stainless Steel SS304

**Net**
- Substitution in kt
Energy Efficiency Standards and Fuel Efficiency Objectives are Currently the Key Environmental Regulations Impacting Substitution

The importance of regulatory pressure as a substitution driver varies across copper products independently from the extent of Net Substitution.

Environmental Regulations as a Substitution Driver

- **Energy efficiency standards** have strong impact on the material decision in winding wire and other electric applications.
- **Fuel efficiency objectives** are key to all automotive parts including automotive wiring, alloy wiring and other alloy products.
- **Electric mobility regulations** will have a significant impact on copper use, but the impact is not yet felt other than utilities install larger capacities for an expected increase in load.
- **REACH** restricts the use of lead-containing brass and may have an impact on the use of plastics with food or water contact in future.
- **End-of-life recycling/disposal regulations** impact the construction of the units but do not seem to impact copper substitution.
- **Green city/ green home concepts** impact copper use and miniaturization as opposed to substitution.

Non-Environmental Regulations as Substitution Drivers

- Building, electric and fire standards constrain copper substitution and it is expected that these standards will become stricter over the next five years.

*Interview Quote: “We don’t have any latent substitution plans ready for when the copper price will increase. However, it is always possible to substitute.”*
The Majority of Copper Products Experienced Low Substitution in 2018 and Expect a Moderate to Strong Future Growth of Copper Use

High expected future growth of copper use and relatively low substitution in 2018.