Global Substitution Indicators

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The following guidelines with respect to compliance with antitrust laws of the United States, Japan and European Community[1] are intended to govern the conduct of participants in copper industry trade association meetings, both at the meeting itself and in informal discussions before or after the formal meeting.

Price: Competitors should not discuss future prices (including terms of sale) of their products. There is no blanket prohibition against the mention of or reference to current or past prices but limits must be observed. Such references or mentions should occur only when necessary in connection with the development of association programs. For example, reference to a particular price level in comparing the cost of a copper product to a competing product is permitted. Whenever possible, such references should be discussed in advance with legal counsel.

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.

New Products: Competitors should not encourage or discourage the introduction of a new product by another competitor or reveal a particular copper company's plans to change the production rate of an existing product or to introduce a new product. No company should disclose to another company whether it is in a position to make or market a new product. New products may be discussed in a technical manner or from the standpoints of competition with non-copper products and general market acceptance. In addition, proposed methods for and results of field and laboratory testing can be considered.

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 Antritrust 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.

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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.

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Examples of Companies Interviewed

Fabricators: 29	OEMs: 14	End users, trade associations, experts: 19
Aurubis, Nexans, Halcor, Mueller Industries, Prysmian Group, Altek, KME, Messingwerk Plettenberg, Virtus Precision Tube	Leoni, Schneider Electric, WEG, Parker, Siemens, Sisme, Motorvia, Rhona, ESB Networks, Rheinmetall Automotive	Copel, Midea, Elica, ICC International Code Council, ECA Excellence in Electrotechnical & Engineering Services, AMPS, APPLiA Home Appliance Europe

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Core Measures of Substitution and Miniaturization

	Explanation
Copper use	**Copper Use 2018** is the copper volume used in an application in 2018.
- Substitution Loss	Potential copper use lost in the application as copper was substituted by competing materials e.g. aluminum, plastics.
+ Substitution Gain	Based on certain factors, such as regulation, copper gained market share and copper use against competing materials.
= Net Substitution	The sum of the Substitution Loss and Gain is **Net Substitution in 2018.**
Net Substitution as a % of Copper Use	
Net Substitution - Loss to Miniaturization	Products are becoming smaller and more efficient, reducing the volume of copper used. Copper is still used in the application.
= Total Loss	The sum of the Net Substitution and the Loss to Miniaturization is the **Total Loss in 2018.**
Total Loss as a % of Copper Use.	

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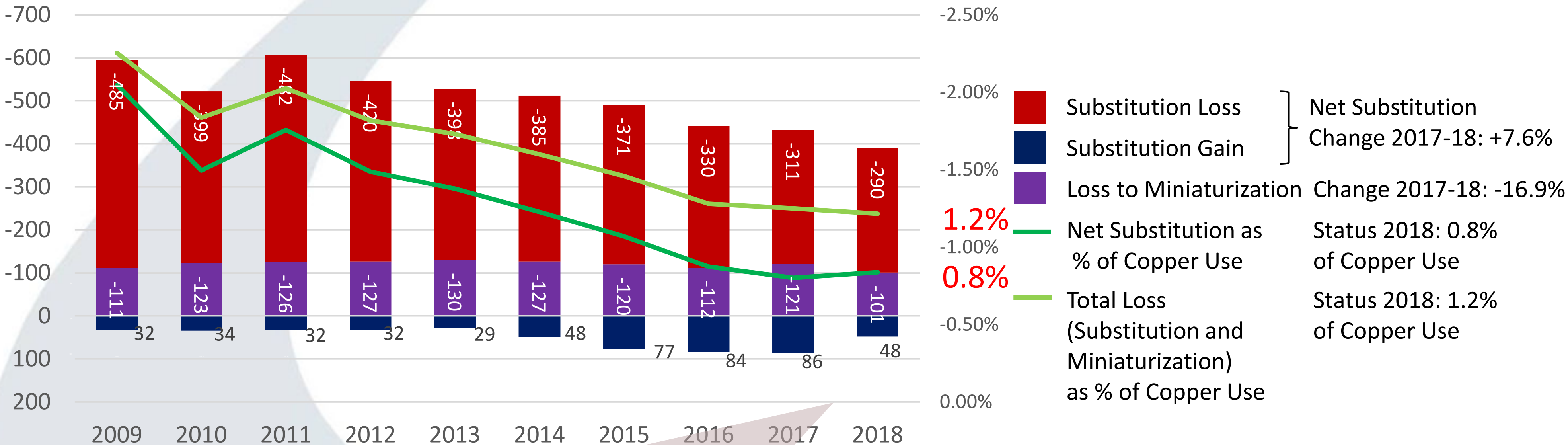
In 2018, Substitution and miniaturization Loss Remained Low at 1.2% of Global Use

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



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.”

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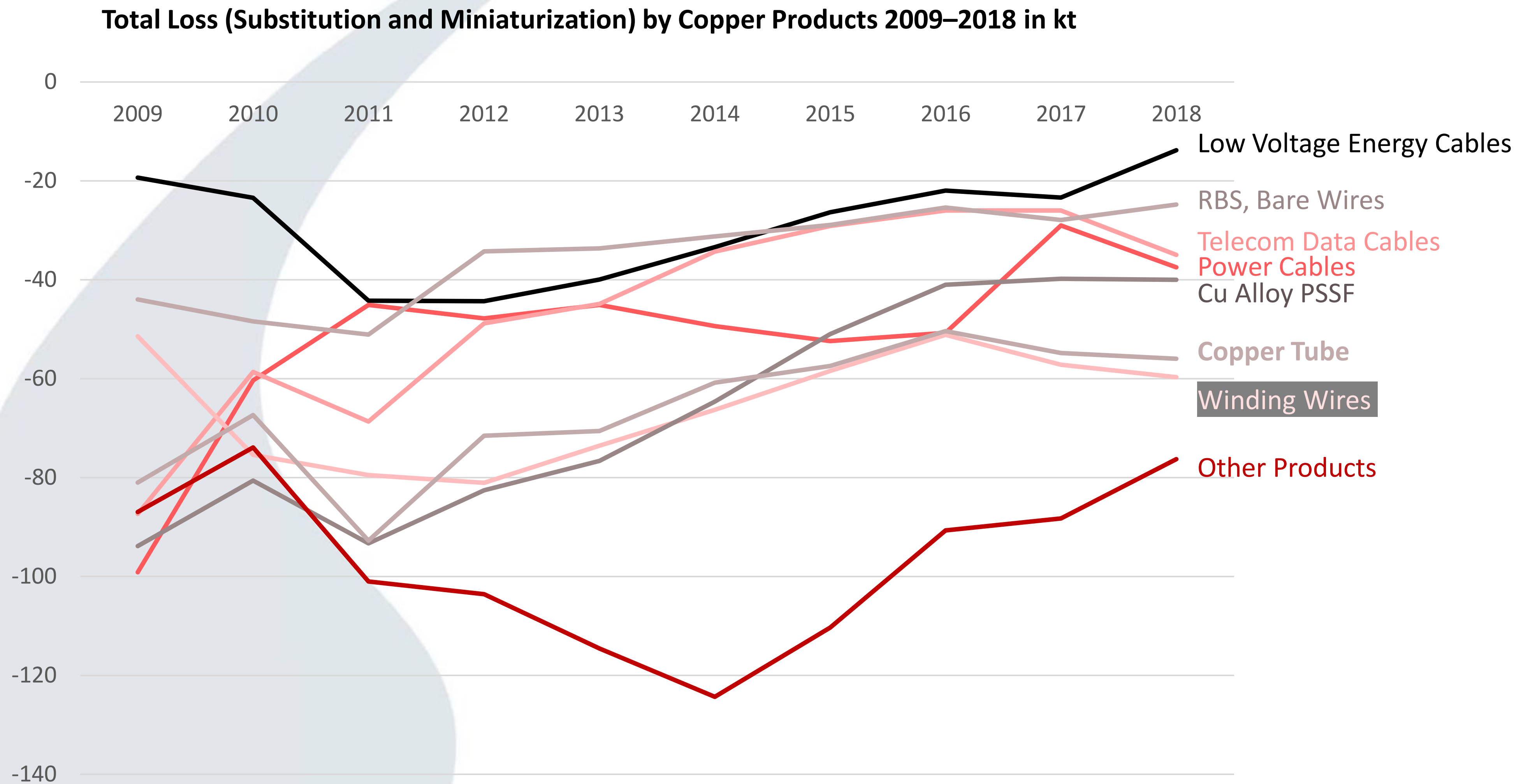
Total Loss has Declined for Many Copper Products



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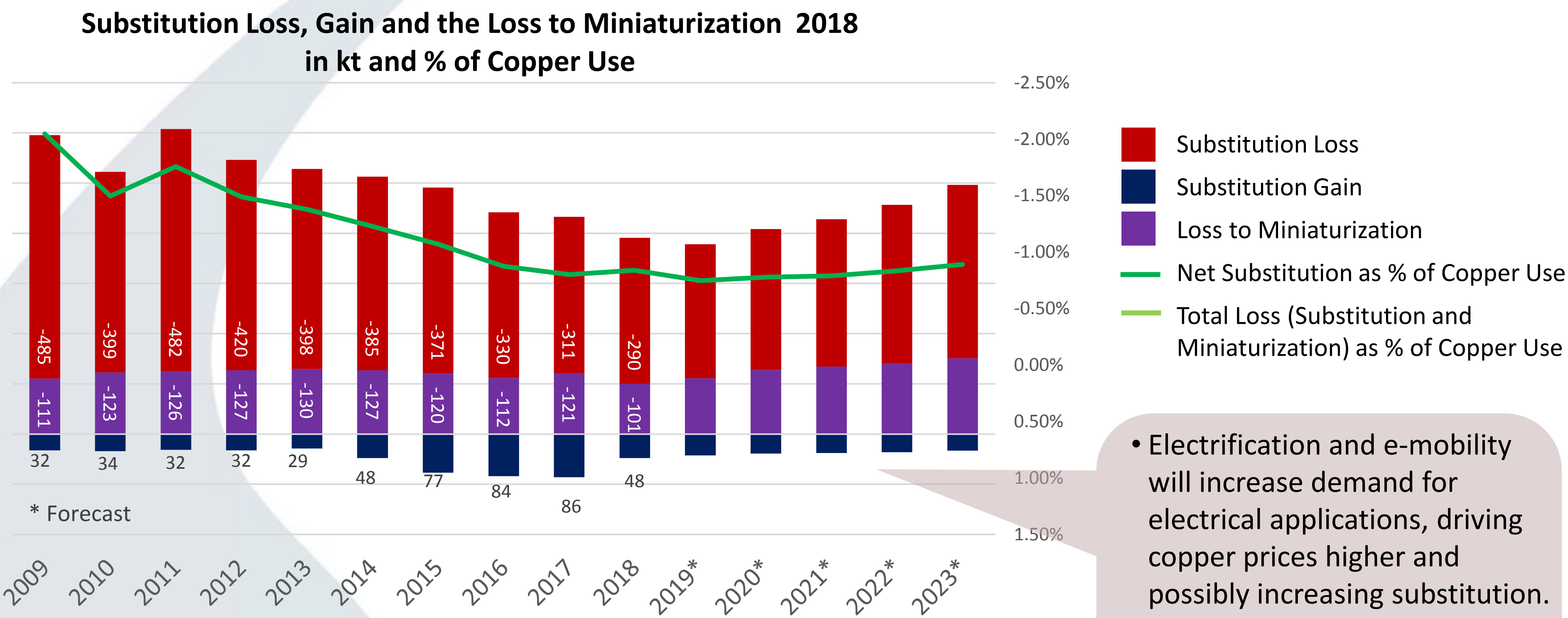
Substitution Expected to Stabilize Before Gradually Increasing



- Electrification and e-mobility will increase demand for electrical applications, driving copper prices higher and possibly increasing substitution.
- New technologies will continue miniaturization.

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

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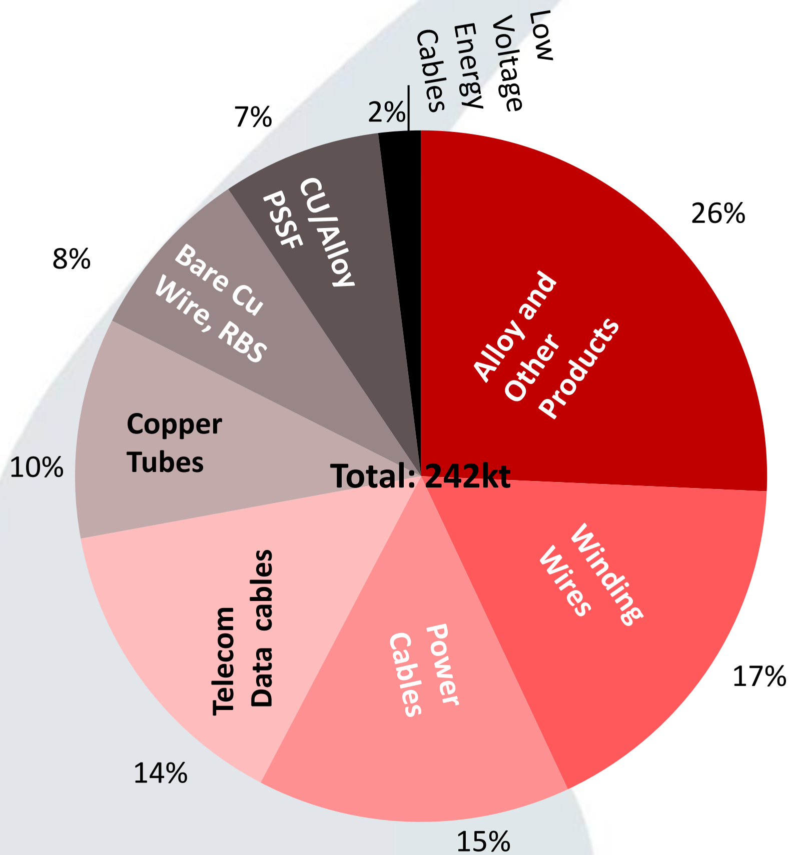
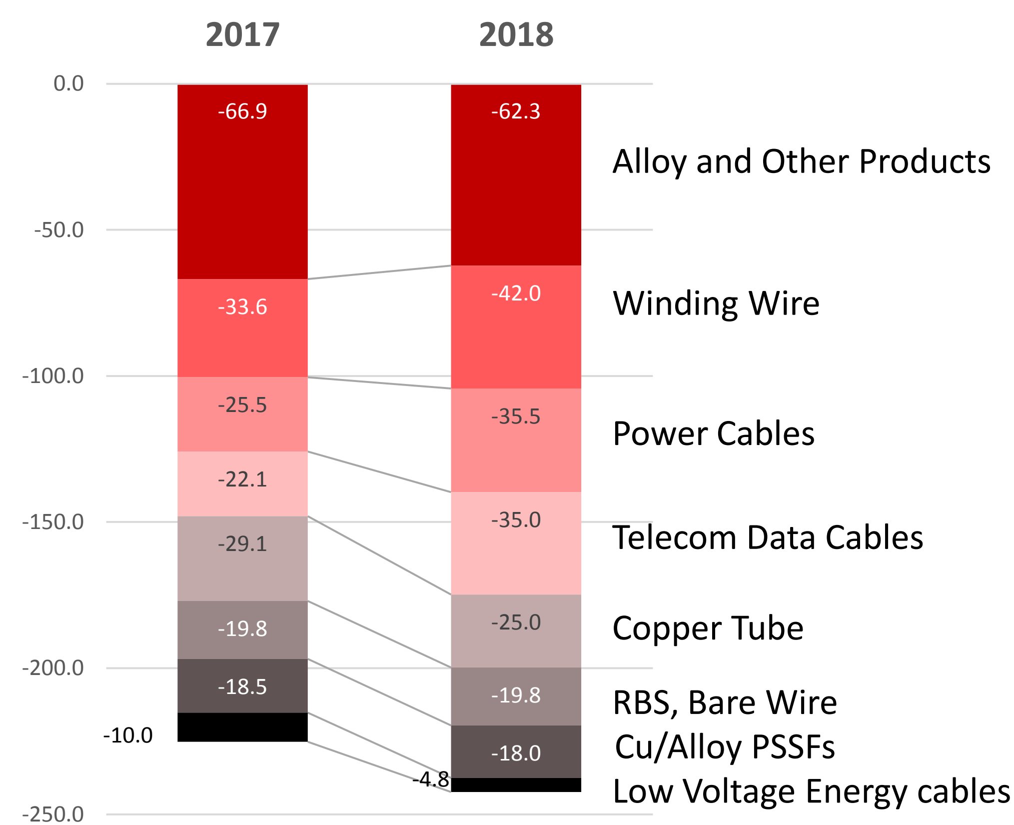
Substitution Share

Distribution of Net Material Substitution by Copper Products 2018 (% of Total)



Net Material Substitution by products 2017–2018 in kt



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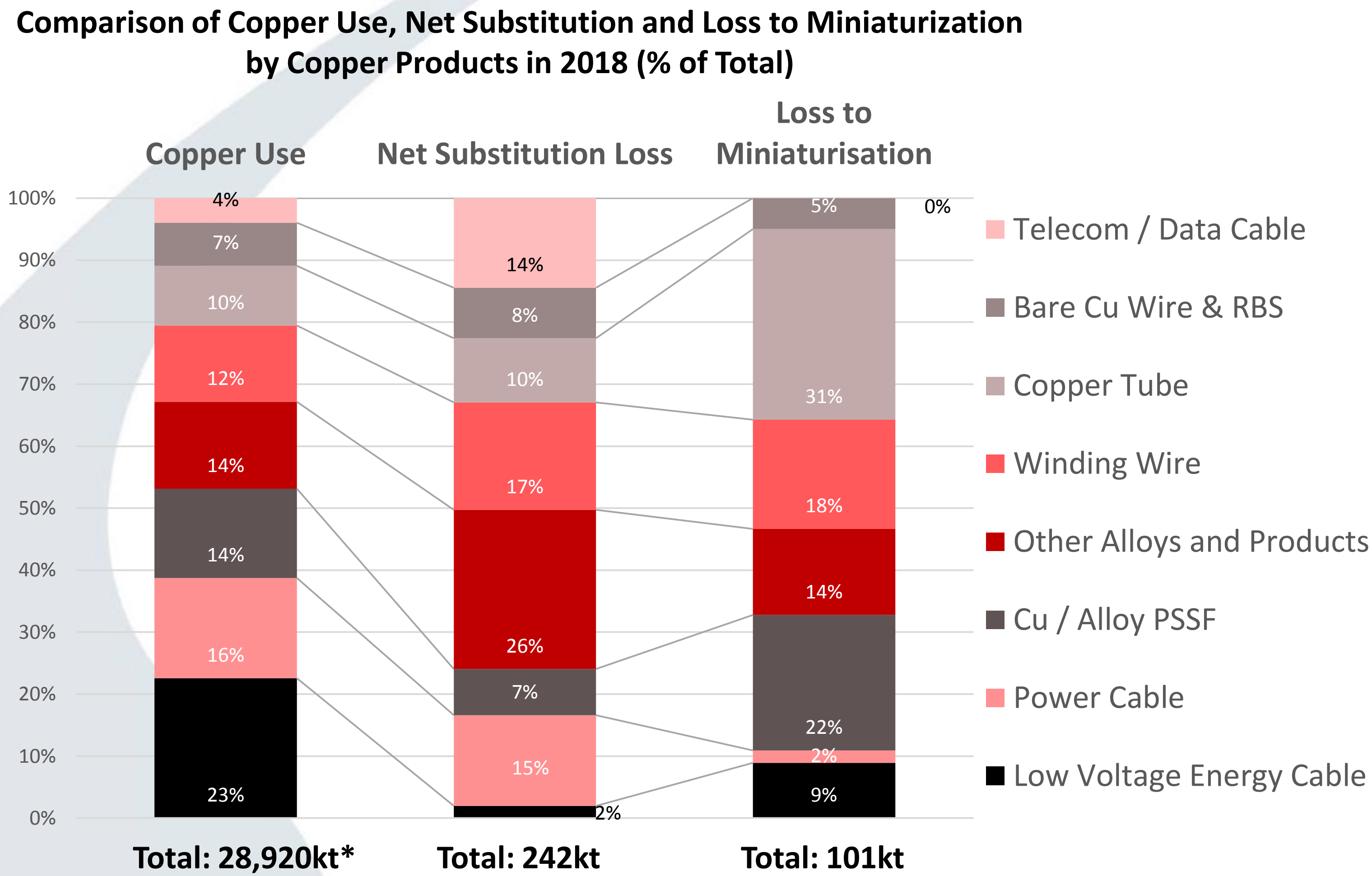
Substitution and Miniaturization Occur Across the Market



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

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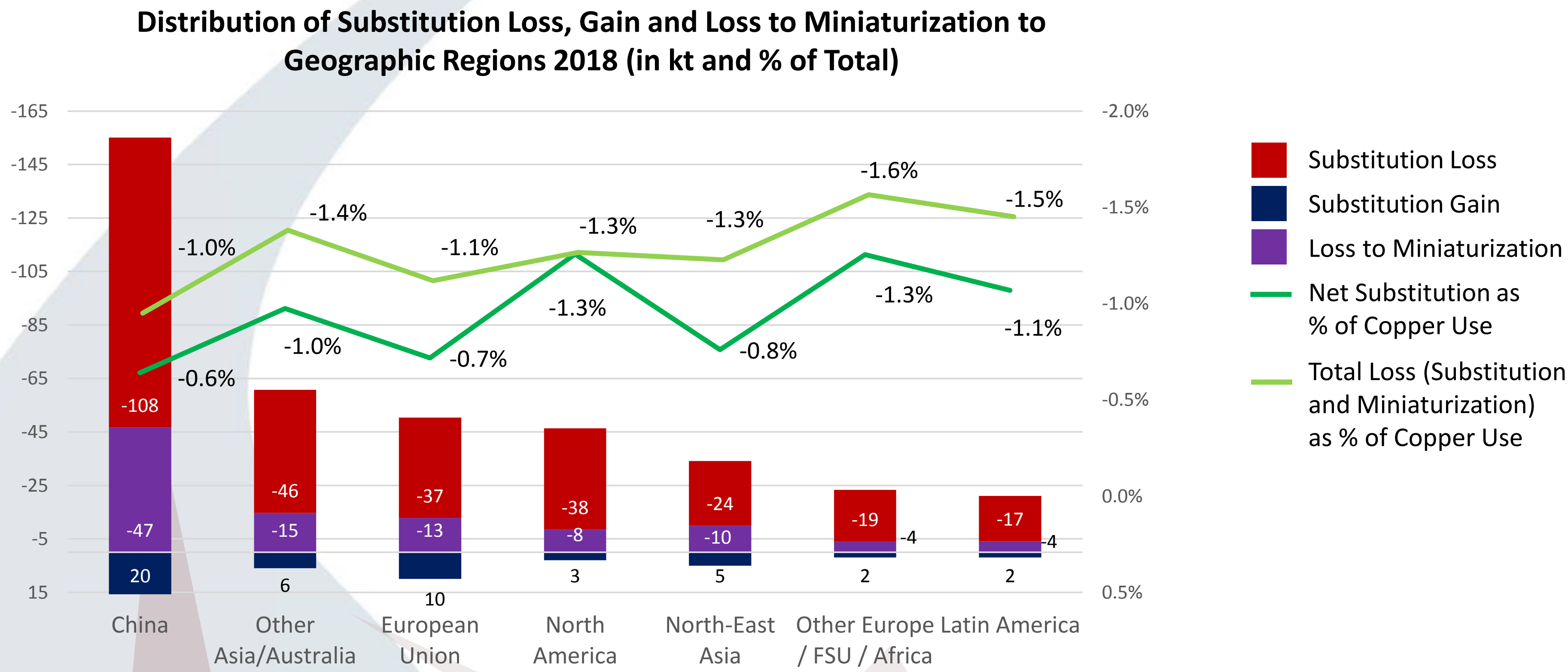
China Contributes Most to Substitution and Miniaturization in Absolute Terms but Least as a % of Use



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.

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China's Preference for Copper is Driven by Focus on Quality and Tradition

China Substitution Loss, Gain and Loss to Miniaturization 2014–2018 (in kt and % of Copper Use)

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.

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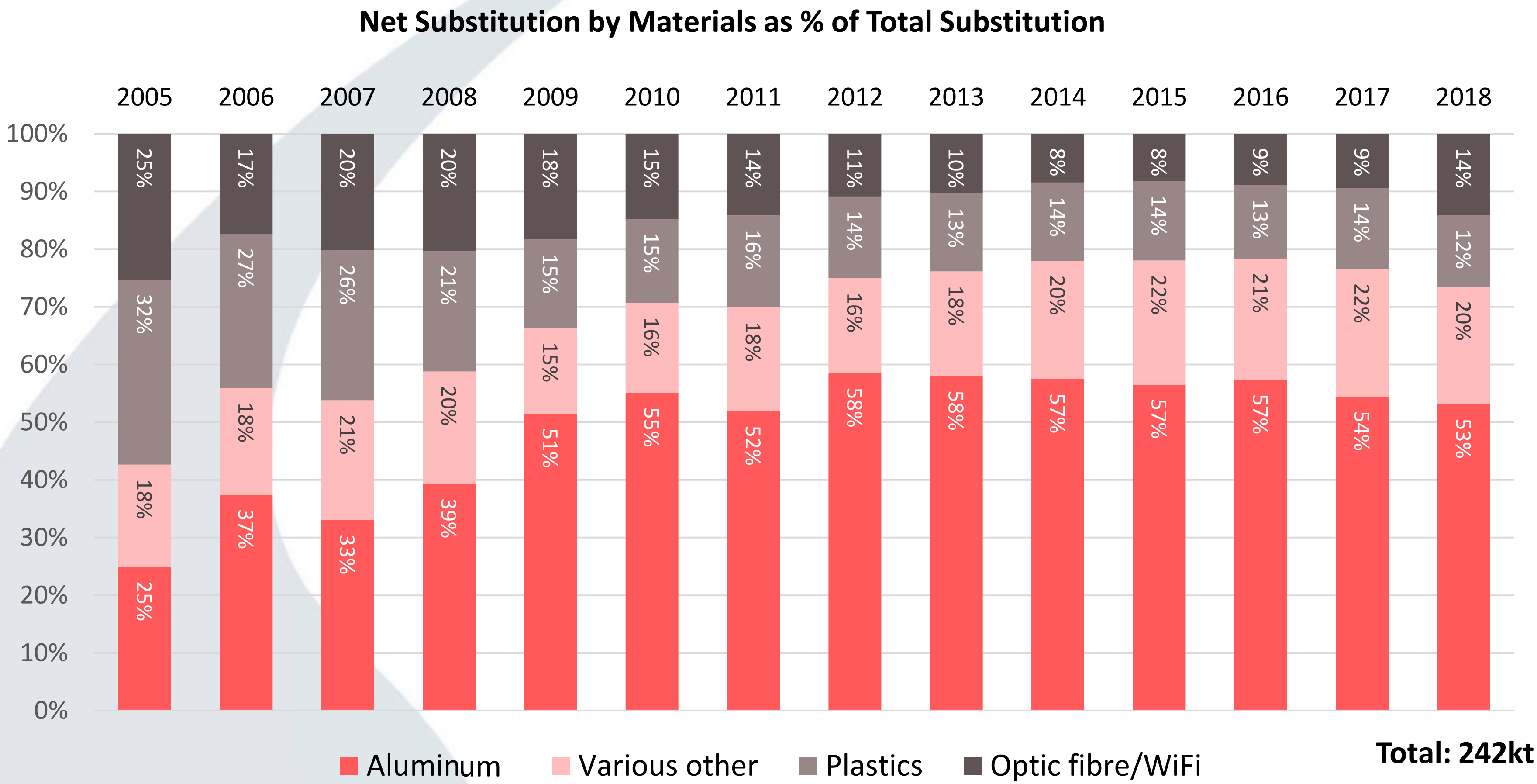
Material Alternatives



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

	Factors influencing material decisons								
	Relative material costs	Relative weight	Relative Footprint	Relative Material Flexibility	Relative Material Strenght	Relative Conductivity	Technology /Connectivity with Other Systems	Regulatory pressure	Pressure from OEMs/end users
Low Voltage Energy Cable									
Building Wire	Relevant	Not relevant	Important	Very important	Applicable	Very important	Applicable	Very important	Applicable
Automotive Wire	Relevant	Very important	Important	Very important	Relevant	Very important	Relevant	Very important	Very important
Equipment Wire	Relevant	Applicable	Very important	Very important	Applicable	Very important	Applicable	Very important	Very important
Power Cable									
Industrial Power Cable	Very important	Important	Important	Relevant	Relevant	Very important	Applicable	Not relevant	Important
Utility Power Cable	Very important	Very important	Applicable	Relevant	Relevant	Very important	Applicable	Not relevant	Very important
Telecom / Data Cable									
External Telecom Cable	Important	Not relevant	Relevant	Applicable	Relevant	Important	Very important	Applicable	Very important
Internal Telecom/Data Cable	Important	Not relevant	Relevant	Applicable	Relevant	Important	Very important	Applicable	Very important
Winding Wire									
Electric Motors	Very important	Relevant	Important	Very important	Relevant	Very important	Very important	Very important	Relevant
Transformers	Very important	Applicable	Important	Very important	Relevant	Very important	Relevant	Very important	Important
Other Winding Wire	Very important	Not relevant	Important	Very important	Relevant	Very important	Relevant	Very important	Relevant

Color code: Very important | Important | Relevant | Applicable | Not relevant

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."

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.

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Factors and Influences 2

	Factors influencing material decisisons								
	Relative material costs	Relative weight	Relative Footprint	Relative Material Flexibility	Relative Material Strenght	Relative Conductivity	Technology /Connectivity with Other Systems	Regulatory pressure	Pressure from OEMs/end users
Bare Cu Wire & RBS									
Copper Rods Bars and Sections	Important	Important	Relevant	Applicable	Very important	Important	Important	Relevant	Important
Bare Wire	Important	Important	Relevant	Relevant	Applicable	Very important	Not relevant	Relevant	Not relevant
Cu / Alloy Plate, Sheet, Strips and Foil									
Electrical / Electronic PSSF	Relevant	Not relevant	Important	Very important	Important	Very important	Important	Relevant	Very important
Other PSSF	Very important	Important	Applicable	Important	Important	Not relevant	Not relevant	Not relevant	Applicable
Copper Tube									
Plumbing Tube	Very important	Relevant	Important	Applicable	Important	Applicable	Very important	Applicable	Relevant
Industrial Tube	Very important	Very important	Important	Applicable	Important	Very important	Very important	Important	Very important
Other Products									
Alloy RBS	Very important	Important	Important	Applicable	Important	Important	Applicable	Relevant	Important
Alloy Tube	Very important	Relevant	Relevant	Relevant	Very important	Important	Applicable	Important	Important
Alloy Wire	Very important	Important	Important	Important	Relevant	Very important	Applicable	Relevant	Important
Foundry Products	Very important	Important	Important	Relevant	Very important	Relevant	Applicable	Relevant	Very important
Other Non Mill Products	Very important	Not relevant	Not relevant	Not relevant	Not relevant	Relevant	Applicable	Relevant	Important

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Interview Quotes: "Efficiency, functionality and price have been the key considerations for material selection for a Chinese motor producer."

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

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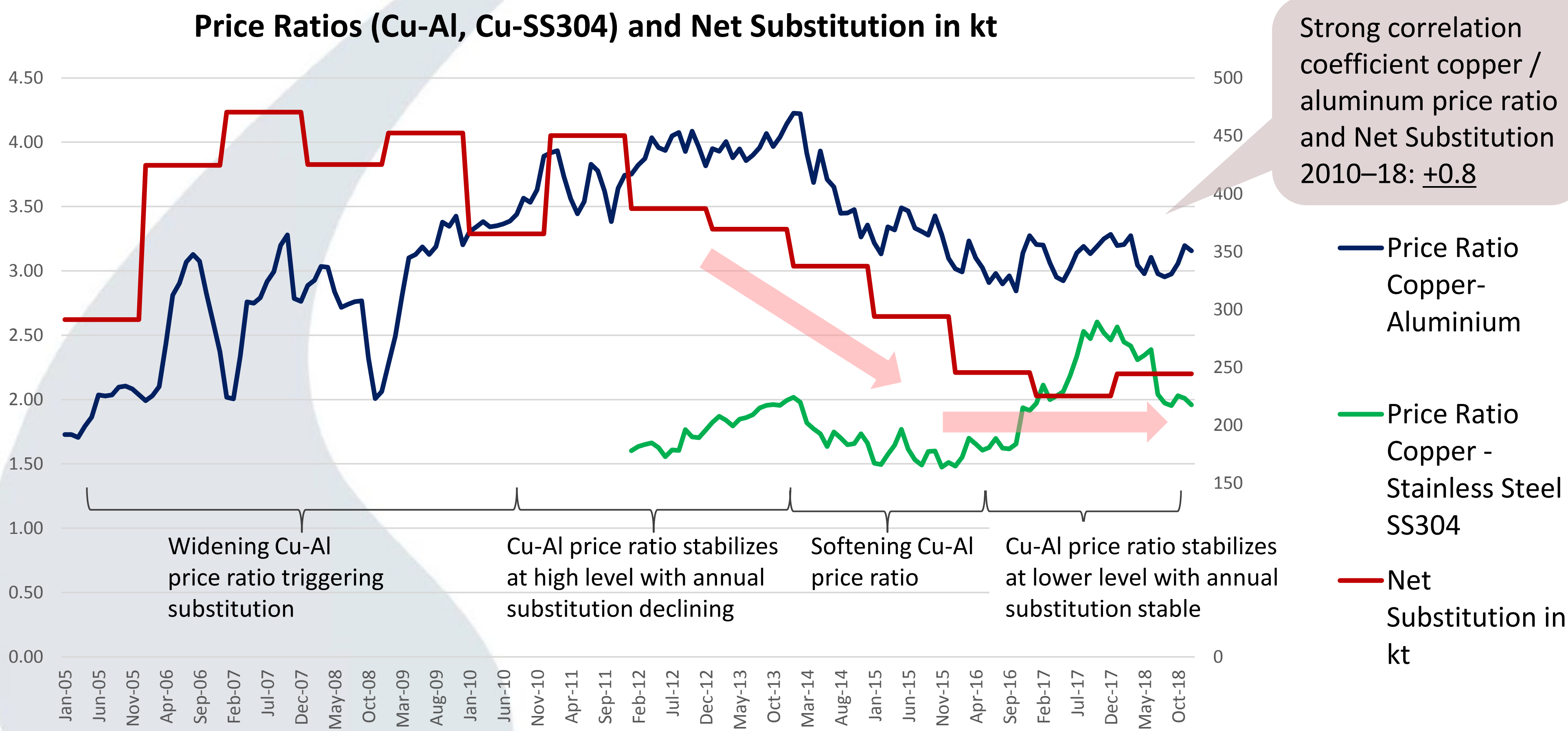
Correlation With the Copper-Aluminum Price Ratio



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

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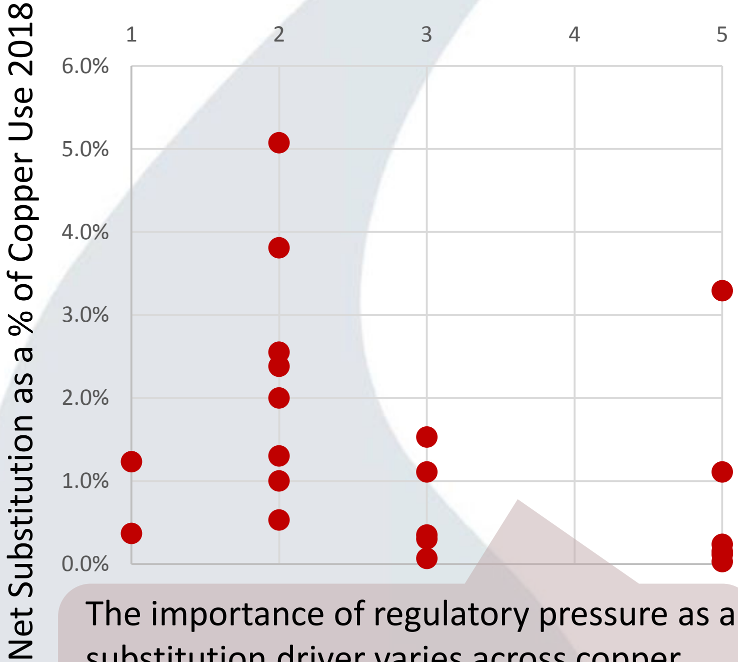
Energy Efficiency Standards and Fuel Efficiency Objectives are Currently the Key Environmental Regulations Impacting Substitution

Importance of Pressure from Regulations in the Material Decision (1: Not Relevant, 2: Applicable, 3: Relevant, 4: Important, 5: Very Important)



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."

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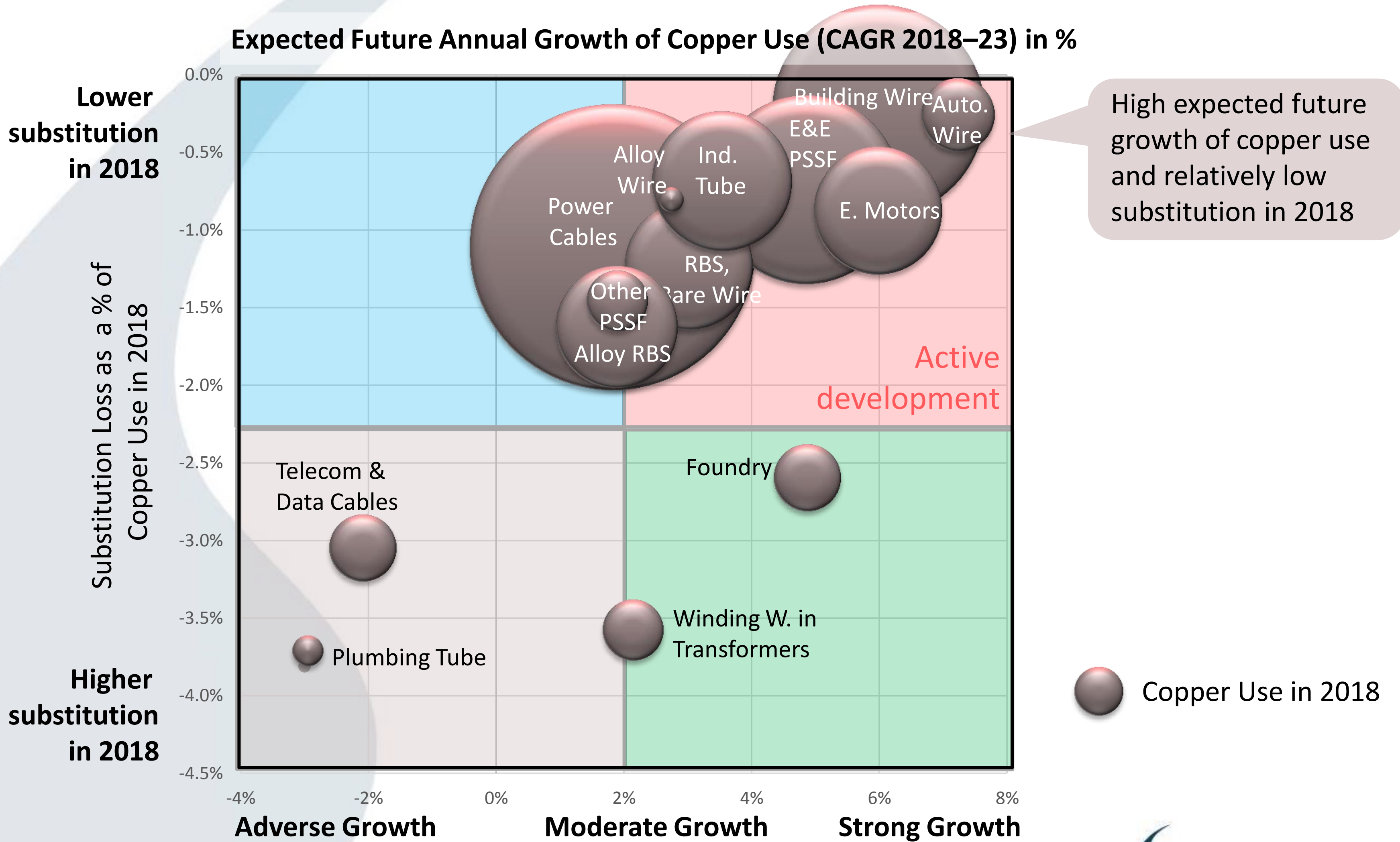
The Majority of Copper Products Experienced Low Substitution in 2018 and Expect a Moderate to Strong Future Growth of Copper Use



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