



Antitrust Guidelines for Copper Industry Trade Association Meetings

The following guidelines with respect to compliance with antitrust laws of the United States, Japan and European Community¹ 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 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.

Disclaimer

- The purpose of the information in this presentation is to guide ICA programs and provide members with information to make independent business decisions.
- The information contained in this presentation has been prepared using information available to DMM Advisory Ltd. at the time of preparation and through carefully selected external information sources, but makes no warranty as to the accuracy of the information from these sources.
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- The purpose of this presentation is to provide an educated view on likely future scenarios, which need to be further explored by the users of the information provided.



Substitution Survey 2020

Krisztina Kalman-Schueler

Summary

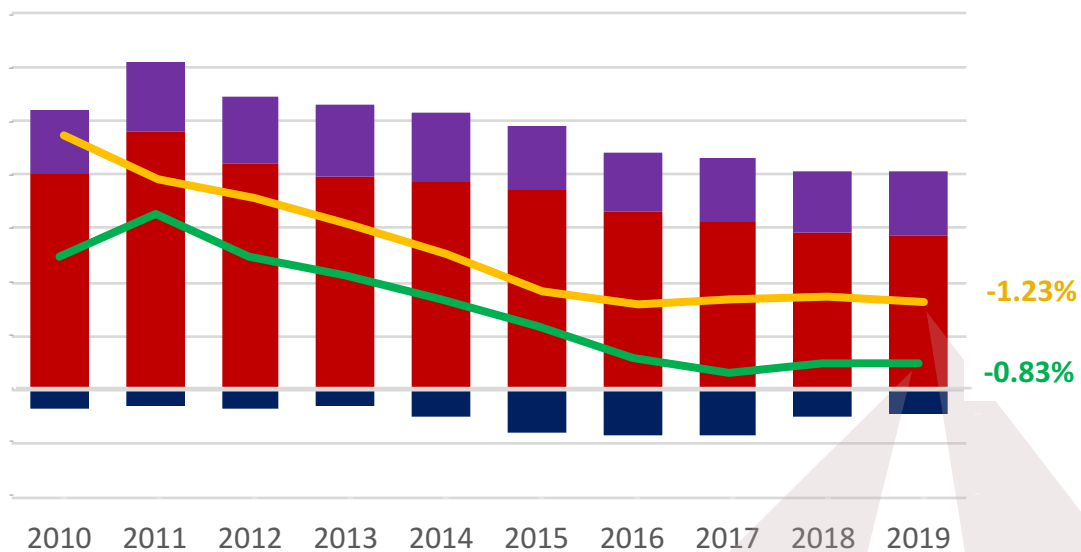
- In 2019, substitution remained stable with net substitution at 0.83% of the copper use.
- New trends supporting copper as opposed to alternative materials became important in the material selection including:
 - Energy efficiency regulations as for the majority of applications it is difficult to reduce electrical loss by using aluminium,
 - Aluminium heat exchangers faced technical issues in many countries, and
 - Critical applications are relying on copper and copper alloys for performance.
- Miniaturisation has increased slightly in 2019 as new technologies offered opportunities for cost reduction without substituting copper. The copper products with the largest contribution to miniaturisation were:
 - Industrial Tubes as smaller diameter copper tubes enabled cost reduction while keeping the many advantages of copper, and
 - Winding Wires in Electrical Motors as new motor designs such as the brushless motors, hairpin motors etc. use copper but achieve a reduction of the copper volume.
- Key factors impacting substitution are relative material costs, regulations/standards, new technologies and pressure from competitors to reduce costs especially in markets with stagnating or declining demand.
- China, the largest copper use region, continues preferring copper as the reliable material and due to regional material specifications.

Examples of companies included in the 100+ interviews and surveys



Net substitution stabilized at 0.83% of copper use, including miniaturization 1.23%

Copper Substitution and Miniaturization
- in kt and % of Copper Use in 2010-2019



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

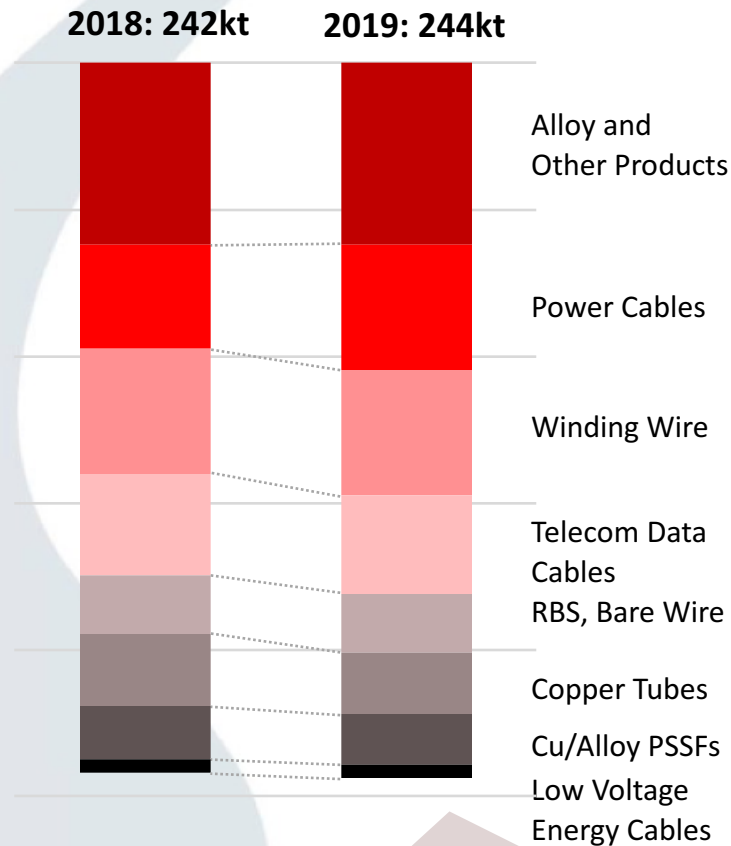
Net Substitution as % of Copper Use : 0.83%
Total Loss as % of Copper Use : 1.23%

- The relative cost of copper and aluminum have not significantly changed over 2019 with a stable impact on substitution.
- While substitution is ongoing, in some copper applications developments favoring copper such as energy efficiency regulations, and advanced technologies in electric motors supported substitution gains.
- Many copper applications have limited exposure to substitution as copper and alloys still provide the best cost-performance combinations, especially where conductivity, heat and corrosion resistance is required.
- Miniaturization is technology driven and 2019 further implemented new technologies for electric motors, and heat exchanger.

Interview Quote: "Substitution has not changed in 2019 but we are preparing for high copper prices."

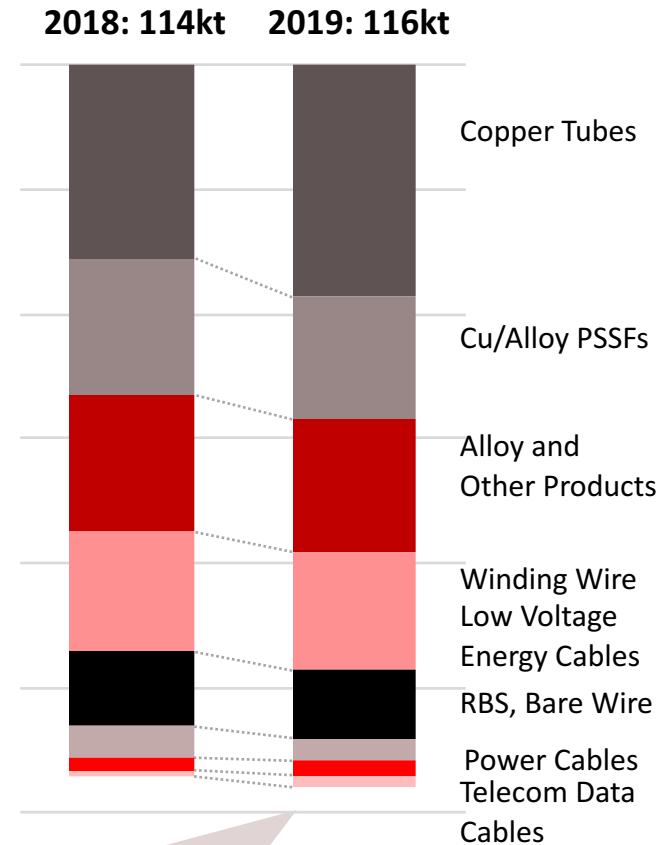
Stability in 2019

Net Material Substitution by products
2018-2019 - in kt



Net substitution in 2019 was driven by Alloys, Power Cables and Winding Wires

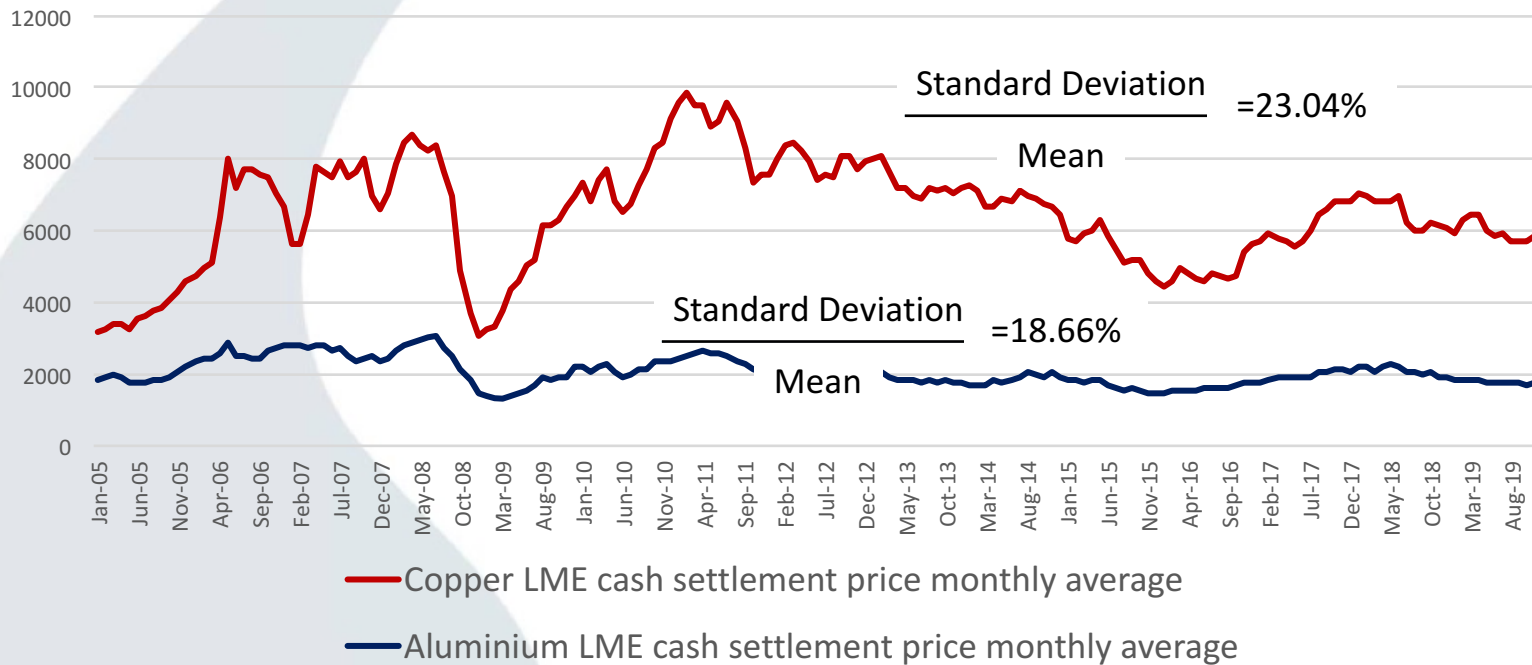
Miniaturization by products
2018-2019 - in kt



Miniaturization in 2019 was driven by Tubes, PSSF, Alloys and Winding Wire

Volatility was raised as a key issue in the survey

Copper and aluminum monthly average LME cash settlement price in \$

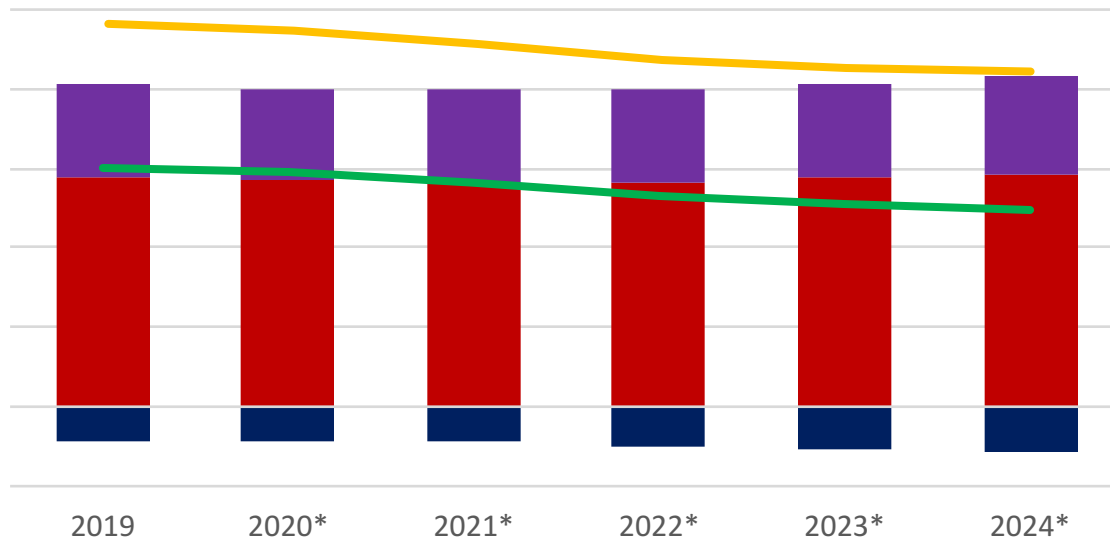


Interview Quote: "Relative material costs are always important, but current copper price does not prompt substitution."

- Manufacturers often need to keep constant prices for years after launching a new product. This means forecasting material prices 2-3 years ahead at the time of the product design and material selection.
- Volatile prices could lock in manufacturers in potentially unprofitable price commitments over a long time.
- Material prices can be hedged on the open market to a certain degree, but this adds to the material costs.
- Instead using materials with volatile prices, if there is an alternative material, many manufacturers select the alternative material with a more stable price.

Forecast: Very low impact

Copper Substitution and Miniaturization
- in kt and % of Copper Use in 2019-2024



* Forecast

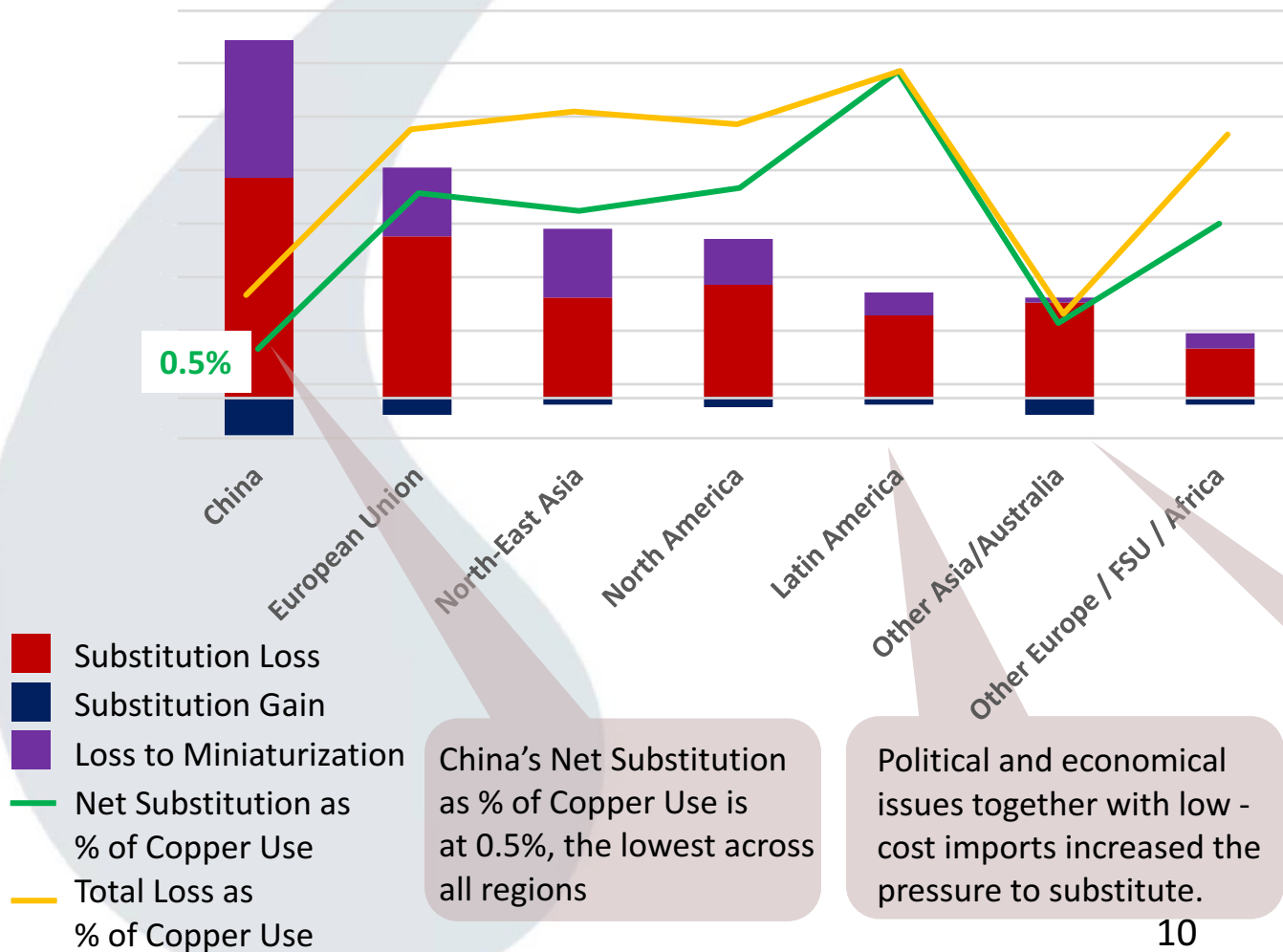
- Substitution
- Substitution Gain
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Interview Quote: "The Chinese economy is moving from an investment to consumer-oriented economy. This will likely lead to stronger cost pressure for utilities with a potential impact on their material procurement policy."

- Over the next five years a very low impact:
 - The substitution gain driven by stricter regulations and energy efficiency, and
 - Miniaturization driven by technology advancements to reduce material costs and frame size.
- At the same time, copper use will increase due to electrification, the use of more electric devices and the electric mobility revolution. Therefore, the % share of the net substitution on the copper use will likely decline.
- More substantial change in substitution is expected from 2024 onwards as copper use pattern (especially in China) might change and technology might bring more innovations with impact.
- Caveat: This forecast is based on the information collected before the outbreak of the corona virus. We expect that the 2020 copper use needs to be downward corrected and substitution might be upward corrected as manufacturers, OEMs and end users will be facing production interruptions and lower demand. The extend of this correction is currently uncertain.
- Furthermore, the forecast assumes no significant barriers to trade and no unforeseeable political, economical and regulatory challenges over the next five years.

Regional Overview: China is still most loyal to copper, other regions' substitution is mainly influenced by the competitive cost pressure local companies face

Substitution and Miniaturization by Geographic Regions 2019 – in kt and % of Copper Use



- China is still the region with the largest absolute substitution and miniaturization but the lowest net substitution as % of copper use, as key copper products generally exposed to substitution underly procurement policies of state-controlled companies, and these stayed loyal to copper.
- Other Asia /Australia driven by India experienced strong economic growth and material substitution is delayed due to strong demand in the utilities sector (power cables and transformers) and the still to be acquired substitution skills.
- Europe, North-East Asia and North America experienced ongoing substitution, where it was possible to be implemented, driven by strong competitive cost pressure and declining overall demand.
- Latin America has the highest % substitution and total loss on copper use. Here political and economical issues of the region, together with the entry of very competitive Far-East producers created a strong need to reduce costs.

China's Net Substitution as % of Copper Use is at 0.5%, the lowest across all regions

Political and economical issues together with low - cost imports increased the pressure to substitute.

Large state-driven electrification projects, economic growth delayed substitution.

Substitution drivers

	Factors influencing material decisions									
	Relative material costs	Relative weight	Relative Footprint	Relative Material Flexibility and Strength	Relative Material Strength	Relative Conductivity	Technology/Connectivity with other Systems	Regulatory pressure	Cost pressure from other manufacturers in the market	Pressure from OEMs/end users
Low Voltage Energy Cable										
Building Wire	Very important	Not relevant	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Automotive Wire	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Equipment Wire	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Power Cable										
Industrial Power Cable	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Utility Power Cable	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Telecom / Data Cable										
External Telecom Cable	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Internal Telecom/Data Cable	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Winding Wire										
Electric Motors	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Transformers	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important
Other Winding Wire	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important	Very important

Color code: Very important Important Relevant Applicable Not relevant

Interview Quotes: "Cables are a commodity and 1-2% price difference can win the contract, but the Chinese imports were 20% cheaper than the US produced cables."

Substitution is driven by a range of factors

	Factors influencing material decisions									
	Relative material costs	Relative weight	Relative Footprint	Relative Material Flexibility and Strength	Relative Material Strength	Relative Conductivity	Technology/Connectivity with other Systems	Regulatory pressure	Cost pressure from other manufacturers in the market	Pressure from OEMs/end users
Bare Cu Wire & RBS										
Copper Rods Bars and Sections	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Bare Wire	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Cu / Alloy Plate, Sheet, Strips and Foil										
Electrical / Electronic PSSF	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Other PSSF	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Copper Tube										
Plumbing Tube	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Industrial Tube	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Other Products										
Alloy RBS	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Alloy Tube	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Alloy Wire	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Foundry Products	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important
Other Non Mill Products	Very important	Very important	Relevant	Very important	Very important	Very important	Relevant	Relevant	Very important	Very important

Color code: Very important Important Relevant Applicable Not relevant

Main drivers or inhibitors of substitution and miniaturization

- **RBS/Bare Wire:** Relative costs, standards, functionality.
- **Electrical /Electronic PSSF:** Relative conductivity, flexibility and workability.
- **Other PSSF:** Costs, application-specific requirements on the material, design.
- **Plumbing Tube:** Technology change, relative costs and installation knowledge of end users.
- **Industrial Copper Tube:** Relative costs, weight, repairability, and technology.
- **Alloys and Other Products:** Relative costs, regulations and temperature and corrosion resistance requirements of the application.

Interview Quote: "Copper alloy applications in Oil & Gas, Aerospace, Electrical and Bearings are not challenged by substitution."

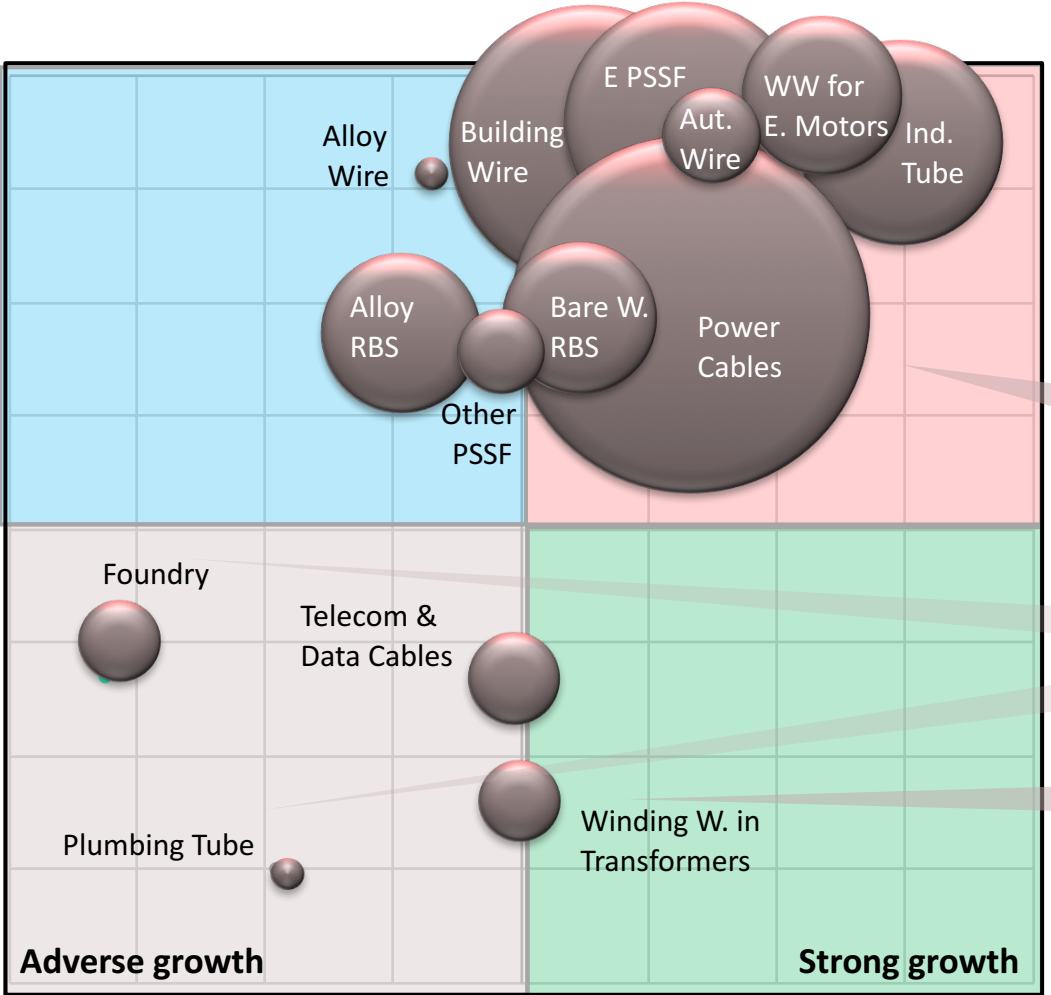
The majority of copper products experienced low net substitution in 2019, and expect a growing copper use over the next five years

Expected future annual growth of the copper use (CAGR 2019-24) in %

Lower substitution in 2019

Net Substitution loss as a % of Copper Use in 2019

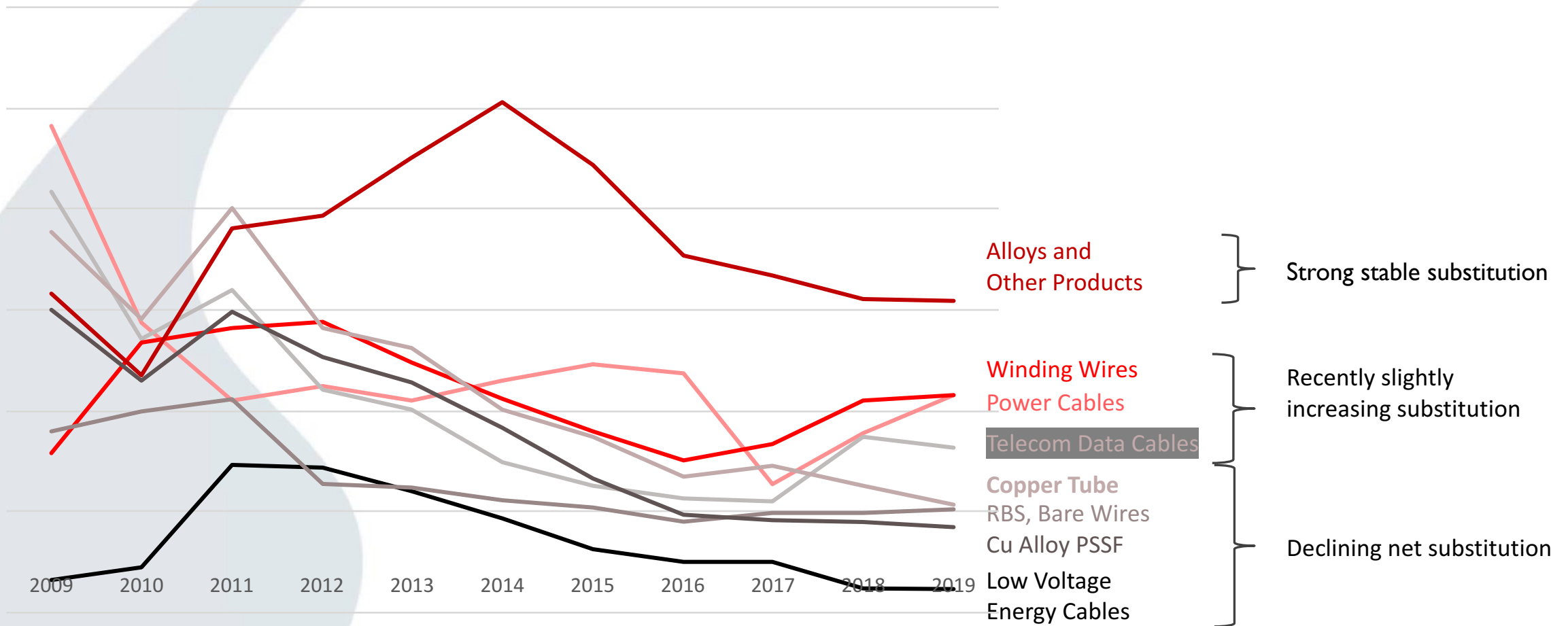
Higher substitution in 2019



- Size of the bubble: Copper Use in 2019
- Expected future growth of copper use with low net substitution in 2019
- Shrinking markets with high substitution
- Stagnating markets and with high substitution

Substitution has declined for the majority of copper products 2009 to 2019

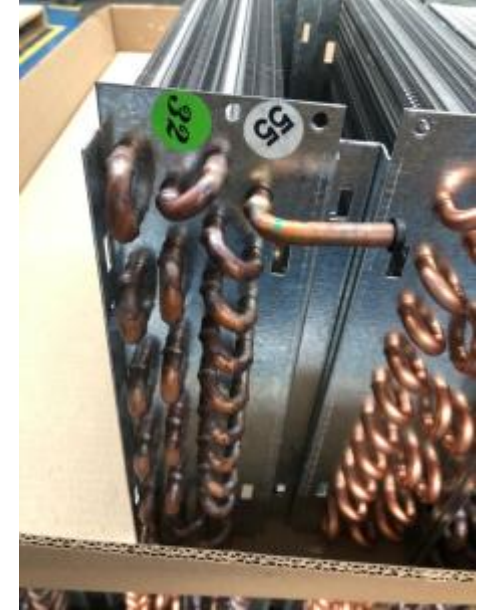
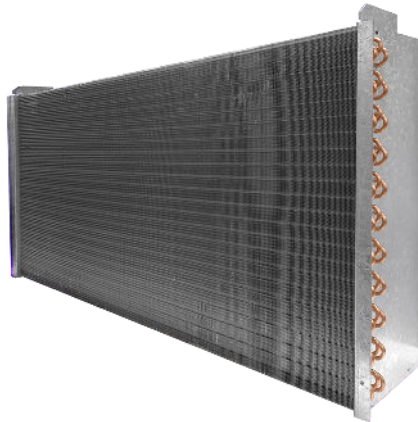
Net substitution by copper products 2009-2019 – in kt



Challenges in the competitive market of refrigeration - Frigus Bohn



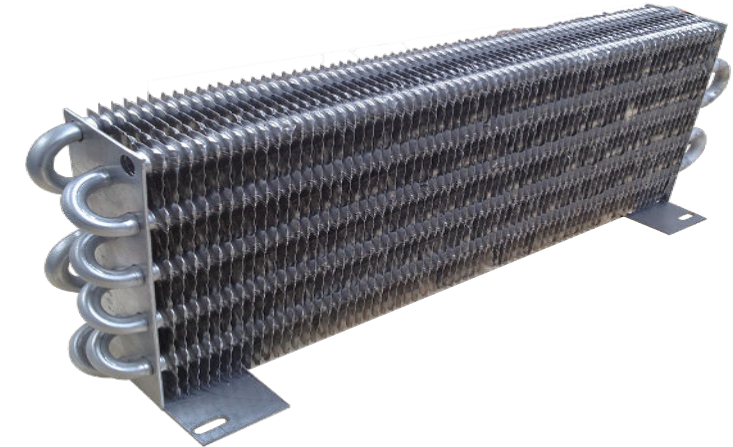
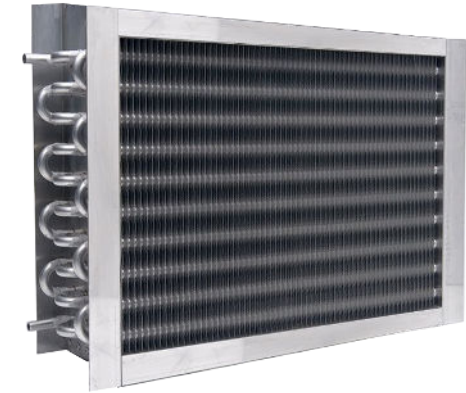
- Frigus Bohn's material strategy is based on copper. The company just invested in a production line using 5mm copper tubes for heat exchangers.
- Refrigeration and air conditioning are very competitive markets where cost reduction is obligatory in order to remain competitive:
 - Reducing the tube diameter to 5mm leading to material cost reduction and less gas charge
 - Mini channel copper aluminum vs. aluminum micro channel
 - Repairable
 - High efficiency
 - Lower gas charge
 - A/C industry using micro channel in residential products
 - Non-repairable
 - Lowest gas charge
 - Good efficiency



Challenges in refrigeration – Frigus Bohn

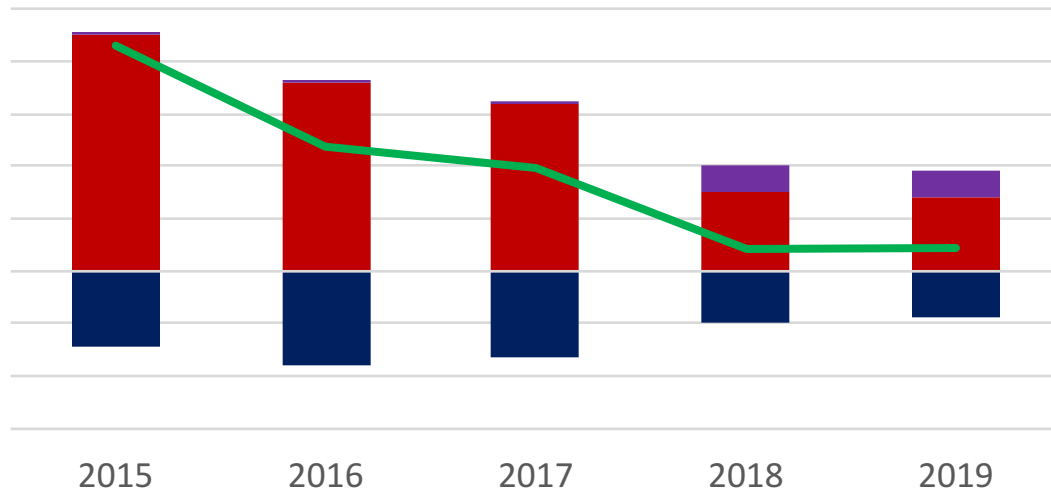


- Further ways to lower cost:
 - From the copper-aluminum coil to aluminum –aluminum coil
 - Cost reduction
 - Less efficient
 - More labor
 - From aluminum –aluminum coil (with return bends) to the zero welds coil aluminum –aluminum
 - Lower cost and propane gas as refrigerant leak reduction
 - Shaded pole motors vs. ECM (brushless) motors
 - Efficiency and more value added



Building Wire – low substitution continues driven by building regulations and physical characteristics of copper

Substitution and Miniaturization
in Building Wire
- in kt and % of Copper Use in 2015-2019



- Substitution
- Substitution Gain
- Loss to Miniaturization
- Net Substitution as % of Copper Use

Interview Quote: "Aluminium is brittle and is only good if the cable has the thickness of a wrist."

Substitution impact - low and stable

- Substitution in the main feeder up to the meter in residential and in some non-critical commercial applications especially if the main feeder is owned by the utility.

Substitution gain – low

- Stricter building regulations in rural areas lead to old aluminium wiring substituted by copper.

Miniaturisation – minimal

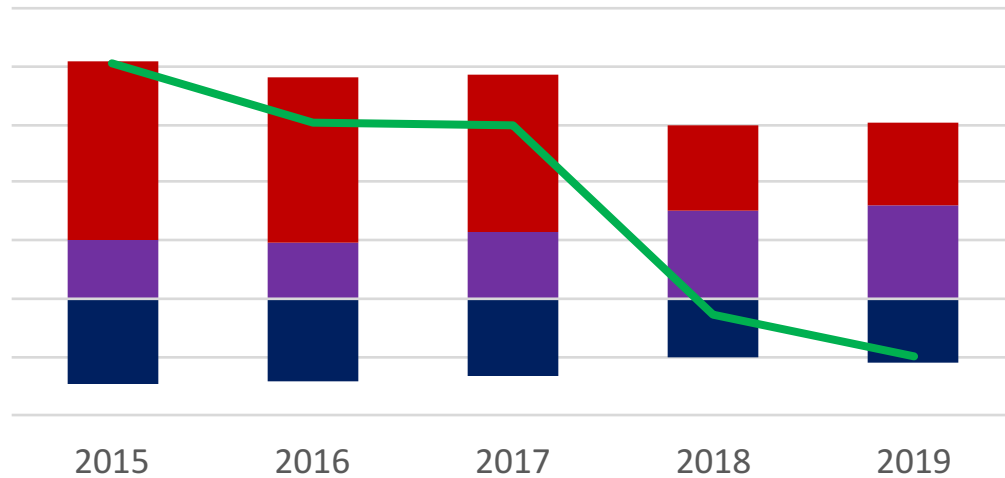
- Theoretically, miniaturisation possible as more energy efficient devices in buildings, and smart technology is used, but technically difficult to implement.
- Power over the Internet did not gain real traction.

Substitution factors

- **Building standards** restrict substitution in building wires especially in residential, urban areas, but even if no restriction in place, often copper used.
- **Flexibility:** Aluminum wire is too brittle to be used for small diameter wires.
- **CAPEX:** no significant cost savings through substitution of copper wires.
- **Fire safety:** Although new evidence does not clearly support higher fire safety for copper, construction companies do not risk using alternative materials.
- **Connections with other systems:** Connecting copper and aluminium is problematic.
- **Building code changes:** Initiatives always exit to more include aluminium in building codes, but these have no traction yet.

Winding Wire in Electric Motors: substitution declined due to increased energy efficiency requirements of motors

Substitution and Miniaturization
in Winding Wires for Electric Motors
- in kt and % of Copper Use in 2015-2019



- Substitution
- Substitution Gain
- Loss to Miniaturization
- Net Substitution as % of Copper Use

Interview Quote: "It is practically impossible to increase energy efficiency with aluminum winding wire."

Substitution impact – declining

- Aluminium is only used in smaller motors where efficiency is not relevant, and in the automotive sector where low weight is paramount.

Substitution gain –ongoing

- Increased energy efficiency generally drives using more copper winding wires and/or using copper as opposed to aluminium bars (40-60% of new designs).
- More efficient permanent magnet and hairpin motors use only copper winding wires.

Miniaturisation – increasing

- High power density, controllable brushless and permanent magnet motors use 20-30% less copper – wide utilisation is slowed by the high price of neodymium magnets.
- Flat conductor can reduce the volume of conductor required for the same performance

Substitution factors

- Combination of cost pressure, load, footprint and energy efficiency:** Each motor design and material selection is assessed based on the combination of required load, space available, cost pressure and energy efficiency status required. The material choice is made investigating the performance requirements and the costs of different materials required for specific types of motors.
- Energy Efficiency:** Increasing efficiency and performance of motors in the same size frame is a trend. It is not possible to increase efficiency with using aluminium winding wires.

Future outlook:

- Reluctance motors efficient and cheaper, expected to gain market share.
- Oxygen-free high-grade copper could support copper-based material strategies.
- Innovations, e.g. high efficiency copper, die cast rotor or axial flux motors.

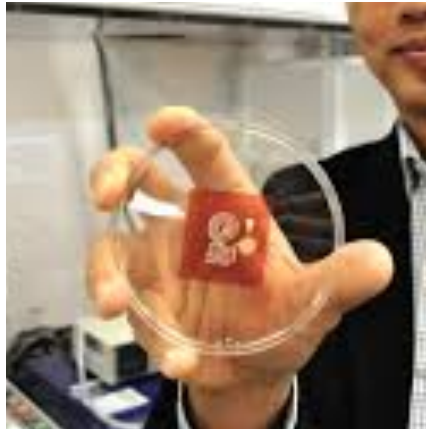
Current and future copper-based innovations

- The industry awaits the new high efficiency, oxygen-free copper to lower electrical losses
- Small diameter copper tubes 1-4mm are becoming feasible
- Copper ink for 3D Printed Circuit Board (PCB) printing is in development
- Flexible PCB
- New high-efficiency motor designs e.g.
 - with more copper in stator and rotor,
 - Zero Porosity Rotor.

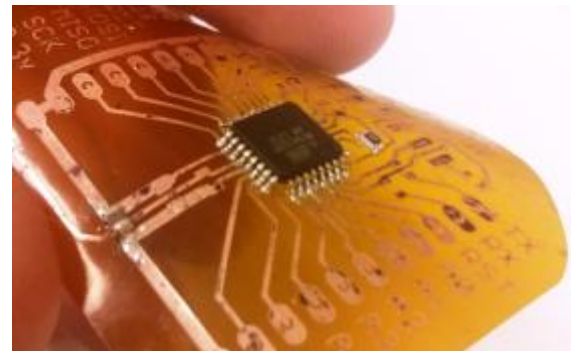
Very small diameter copper tubes



Copper ink based 3D PCB printing



Flexible PCB



Zero Porosity Rotor by breuckmann eMobility

