6XXX-SERIES ALUMINIUM ALLOY WITH HIGH ELECTRIC CONDUCTIVITY FOR EV BATTERY COMPONENTS

Dr. Josef Berneder

Josef.berneder@amag.at

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Agenda

1 Introduction conductor materials
- 1.1 Applications
- 1.2 Comparison of aluminum with copper
- 1.3 Aluminum alloys & manufacturing processes

2 Test procedure
- 2.1 Factors for electric conductivity
- 2.2 Manufacturing process of 6xxx grades
- 2.3 Lab trials

3 Results and discussion

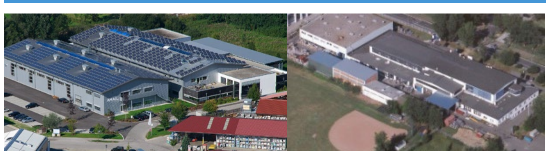
4 Conclusion

AMAG AUSTRIA METALL

AMAG Profile

20% interest in the Canadian smelter Alouette

Integrated site in Ranshofen, Austria



AMAG components, Germany

- **Sites**
  - **Ranshofen (Headquarters, Austria): Most modern aluminium rolling mill** in Europe
  - **Sept Iles (Canada): Secured supply of raw materials** with its interest in the Alouette smelter
  - **Übersee, Karlsruhe (Germany): AMAG components** (a member of AMAG group since November 2020) is a leading producer of ready-to-install metal parts for the aircraft and space industry
  - Proven **strength in reycling**
  - **Growth potential:** Rolling capacity of 300 kt with free capacities currently of around 70 kt
  - **Wide product range** with high share of **specialty products**
  - **Regional focus Europe:** Customer base and primary sales market in Europe is 65 %

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The path to a Net-zero AMAG

Strategy: Sustainability, Innovation, Recycling

2022

Topics	Measures / Milestones
R&D	▪ Material ▪ Plant and Processes ▪ Expansion of recycling and alloying expertise
Energy efficiency	▪ Energy-efficient new plants ▪ Process optimization ▪ Reduction of the heating energy requirement / waste heat utilization
Infra-structure	▪ One of the largest rooftop PV systems (Austria), Buildings „solar-fit“ ▪ Modernizing heating network ▪ Infrastructure for renewable gases (e.g. H_2)
Substitution of energy sources (newly built / rebuilt)	▪ Expansion of Recycling Center Ranshofen (RCR) ▪ Casting (Smelting- / Casting- / Homogenization furnaces) ▪ Rolling mill (Shock furnaces and Continous-heat treatment furnaces)
Delivery chain	▪ Optimized primary aluminium and supplier portfolio

Targets

- Net-zero facility
- Climate-optimised products
- Resource-saving production

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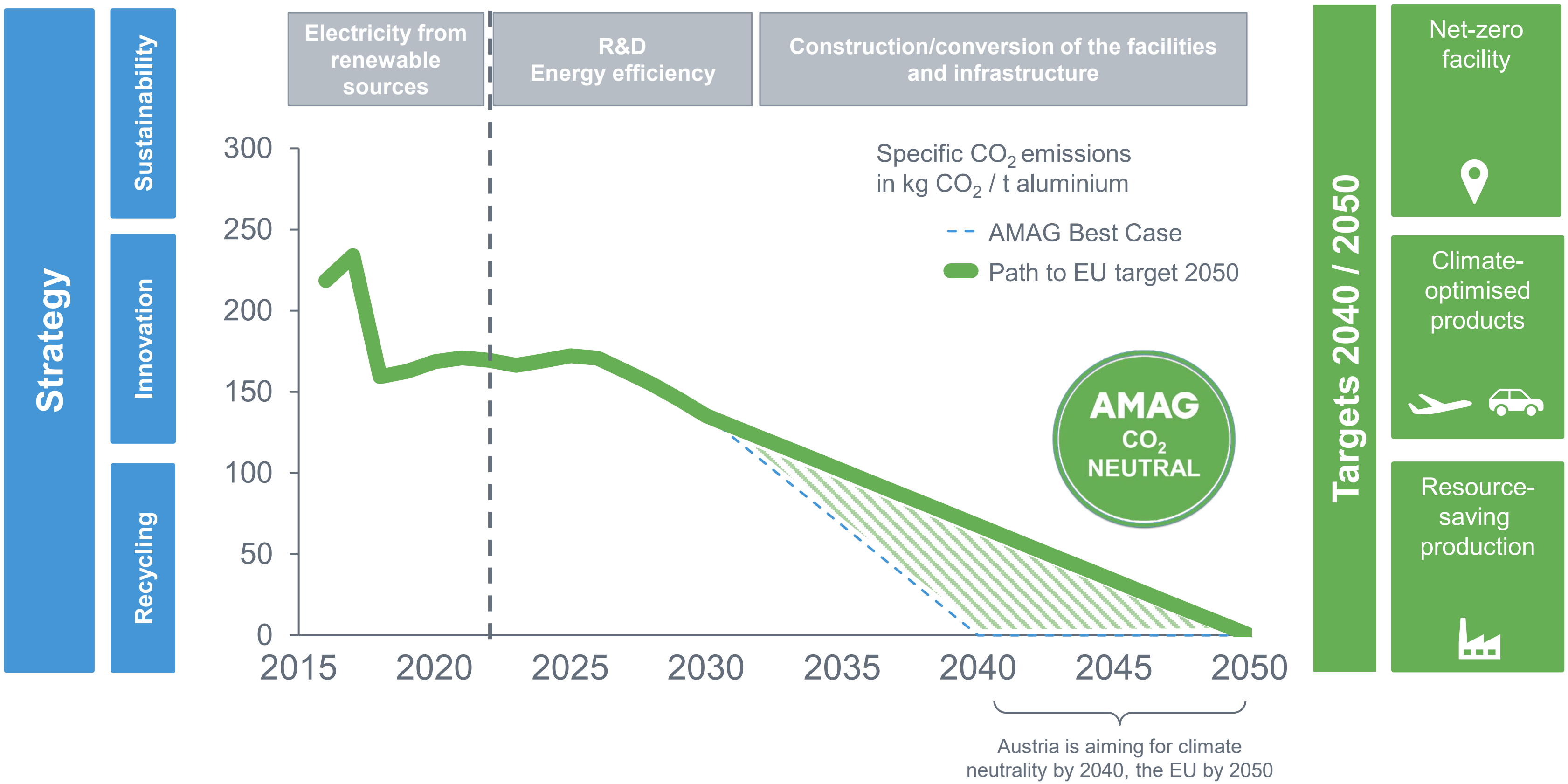
The path to a Net-zero AMAG



Expansion of one of Austria's largest rooftop photovoltaic systems

(from June 2024 onwards – 120,000m²)

Electricity exclusively for own use by AMAG

AMAG AUSTRIA METALL

PV system

Key facts

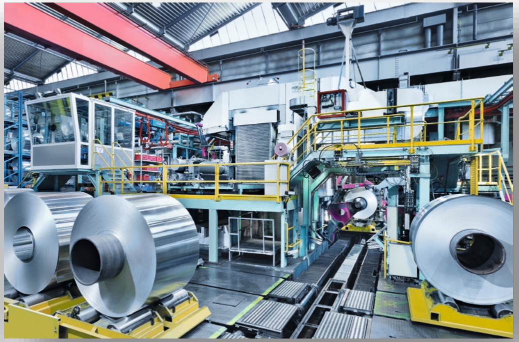
Output 7.5 MWpeak	Yield 7.3 GWh
Connected load of 70,000 refrigerators	Energy requirement of 2,000 households

Innovation

Strong customer relationships through innovative products

AMAG's innovation efforts focus, among other things, on:

- The manufacture of products that promote the use of aluminium and its sustainable development (e.g. **AMAG AL4® ever**)
- The new and further **development of recycling technologies** for the optimal use of materials (e.g. Alloy-to-Alloy recycling)
- Increasing the share of **special products** for the best customer solutions through process and alloy development



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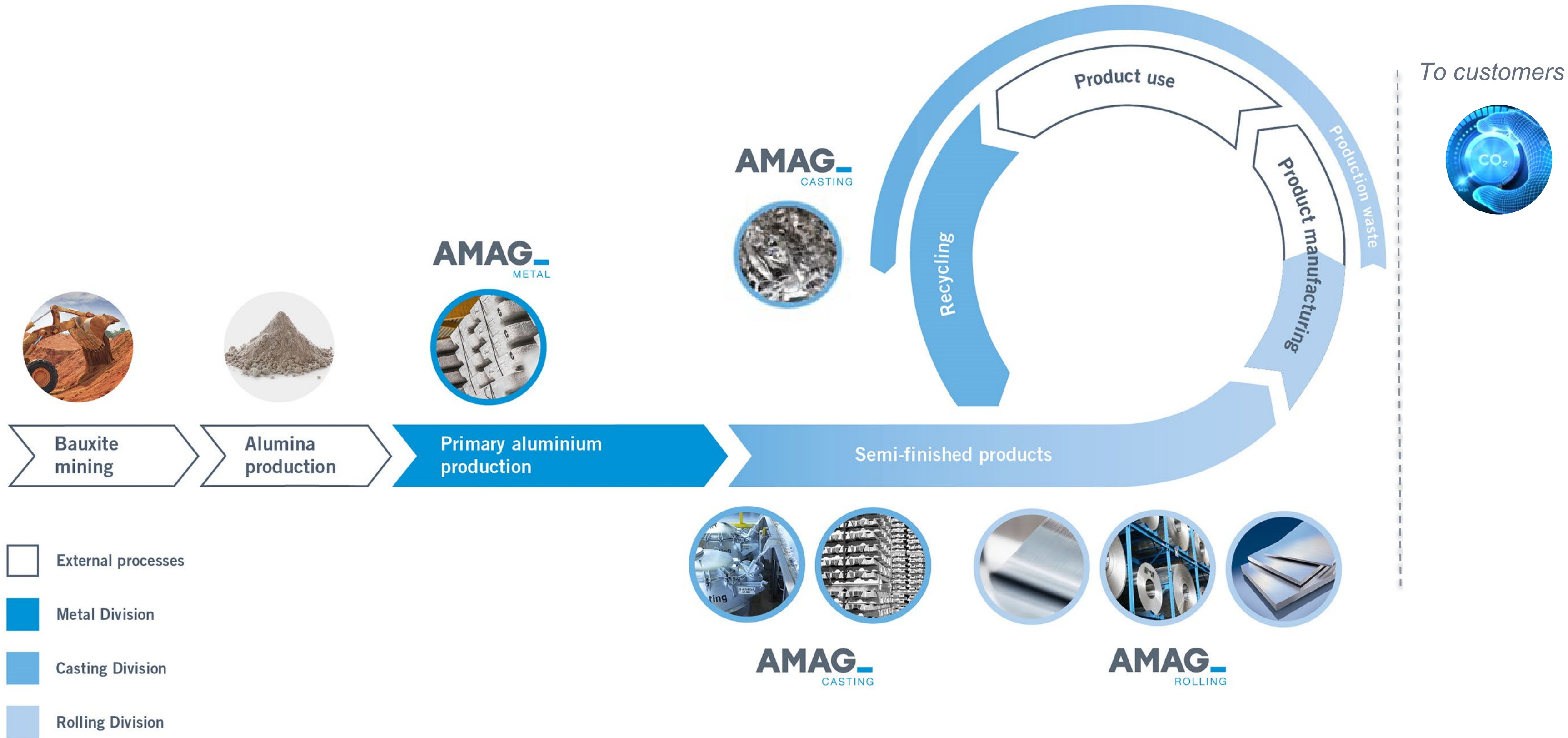
The Aluminium value chain

Uniquely sustainable: cradle–to–gate and closed-loop-system



Recycling @ AMAG

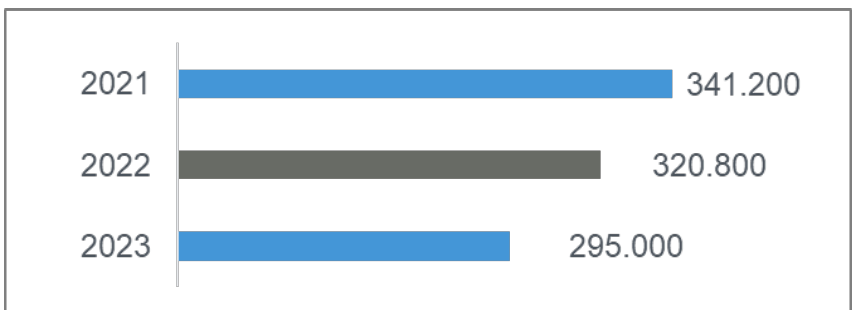
AMAG is a leader in recycling

Systematic expansion of the Recycling Center Ranshofen

Most modern scrap sorting plants using LIBS and X-ray technology

- Ranshofen: is one of the **biggest scrap recyclers** at a single site in Europe
- AMAG processes **all scrap* types** available on the market to create high-quality **specialties**
- **AMAG** is certified according to **ASI CoC Standard**

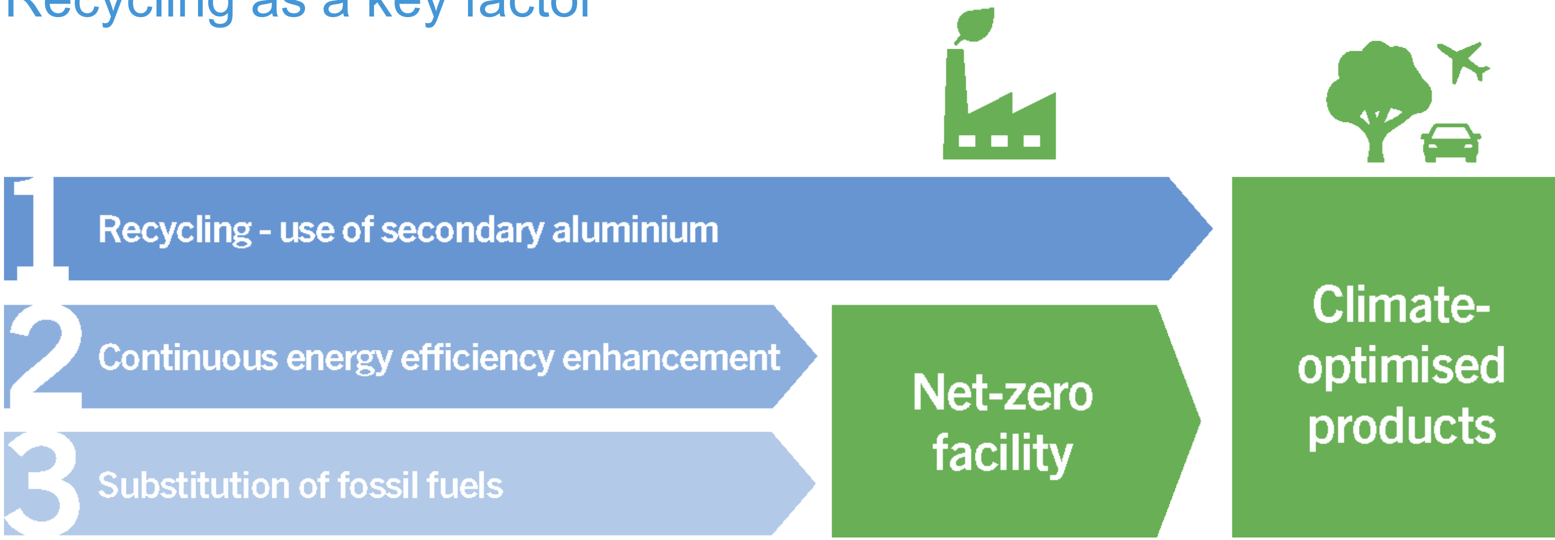
Scrap input in Ranshofen in tons



*purchased external scrap and recycling scrap from the company's own production

The path to net-zero AMAG (1/3)

Recycling as a key factor

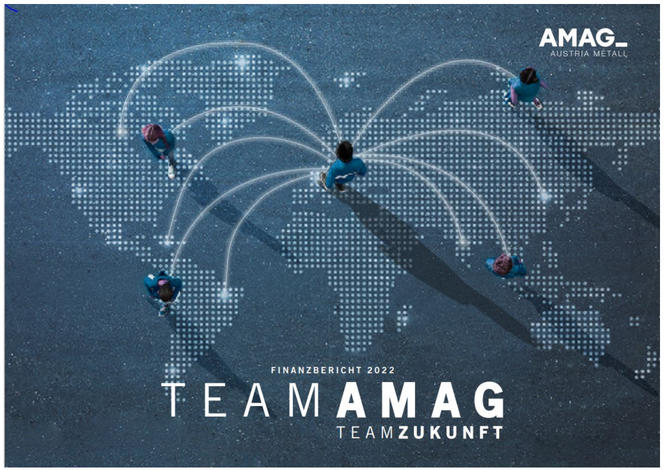


Three levels build upon each other:

- Recycling substitutes CO_2-intensive production of primary aluminium
- Energy efficiency reduces energy demand
- Substitution of the remaining fossil energy sources with future technolgies

Transparent reporting

Transparency in sustainability is a major focus for us



- **Non-financial statement 2022** was published with the annual report on 17.02.2023
- **Audit and review** of the non-financial statement was completed very successfully
- **Prospects:**
  - Monitoring of targets for 2023
  - Preparation for EU-wide reporting standards according to CSRD*
  - Regular implementation of ratings and certifications

*Corporate Sustainability Reporting Directive

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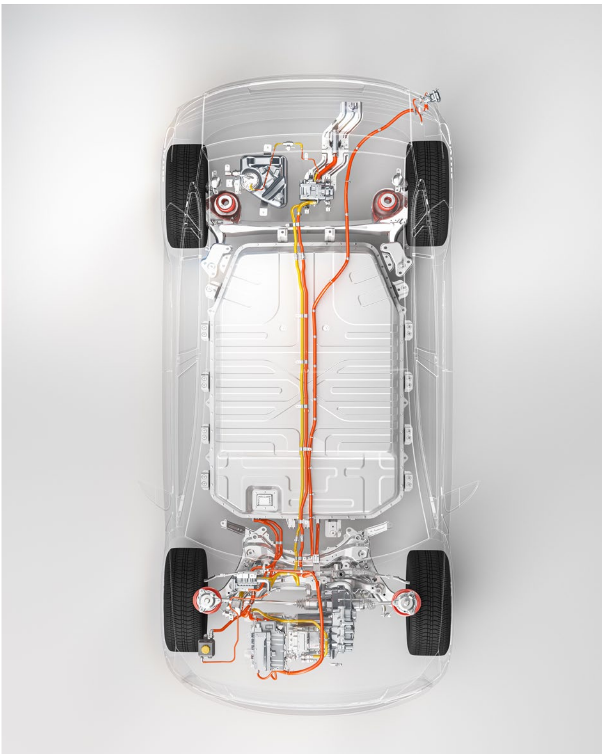
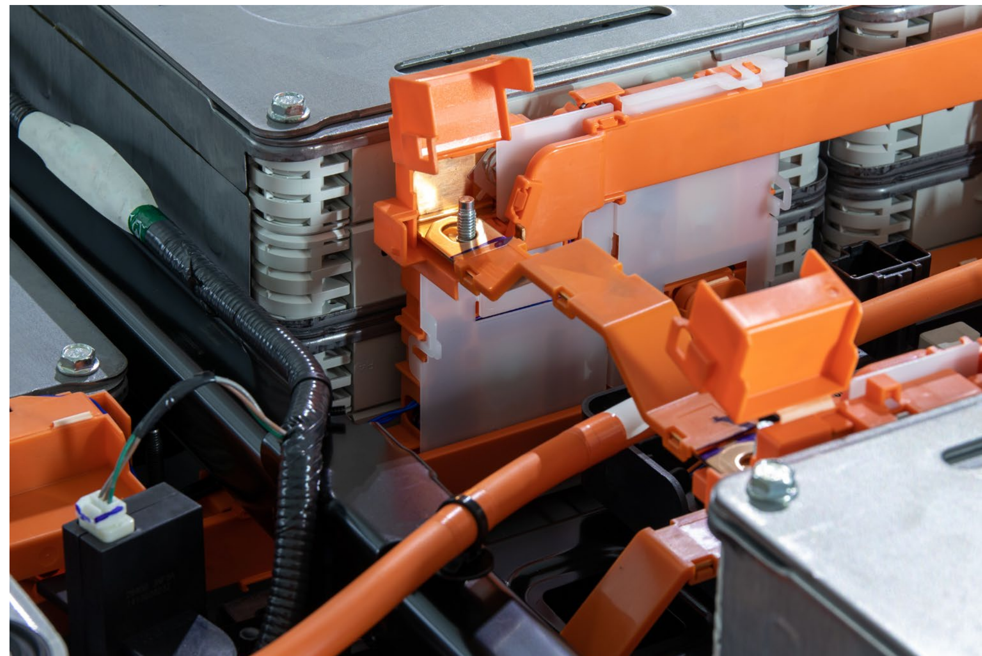
1 Introduction conductor materials

1.1 Applications

Several components within electric vehicles





1.1 Applications

Energy transport and storage

- Additional tailwind from the energy transition

1.2 Comparison of aluminum with copper

Properties

Disadvantages over copper:

- Aluminum has lower electric conductivity
- Higher cross-sections to transport the same amount of electricity required with similar system resistance
- Oxide layer of aluminum is not conductive
- Lower thermal expansion of copper

Advantages over copper:

- Weight-specific higher electrical conductivity
- Improved strength to weight ratio
- Raw material costs and material availability

2 Test procedure

2.1 Factors for electric conductivity

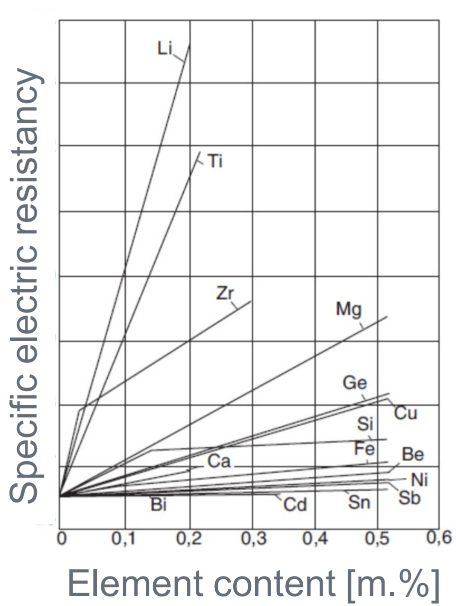
Alloy elements have significant influence

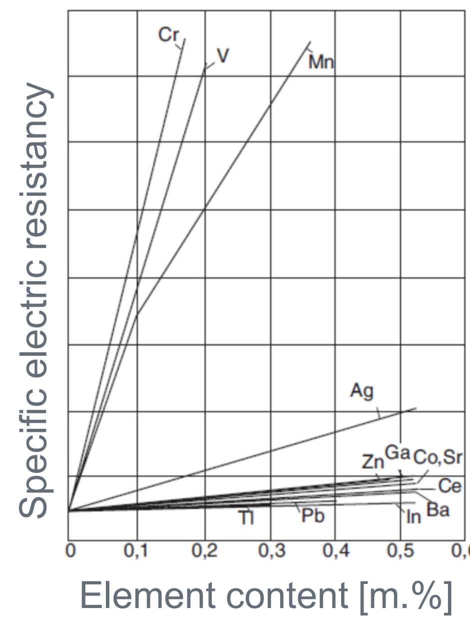
- **Grain size**
  → Coarse grain increases electric conductivity
  → Negative impact for bending ability
- **Chemical composition**
  → Amount of alloying elements and their condition in the structure
  → All solutioned elements hinder the movements of electrons

2.1 Factors for electric conductivity

Alloy elements have significant influence

- Mn, Cr, V and Mg have the largest negative lever for electrical conductivity

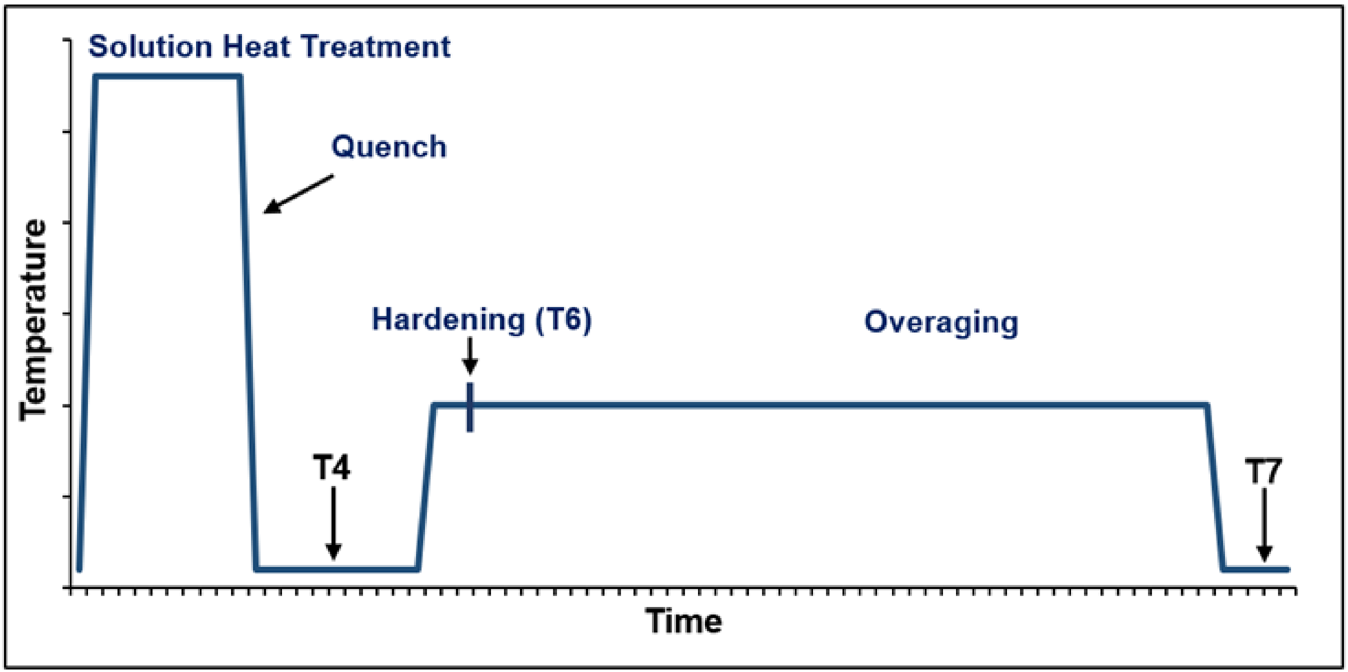




Kammer C (2022) Aluminium-Taschenbuch. Aluminium-Verlag, Düsseldorf, p 232-233
Kutner F (1980) Leitwerkstoffe aus Aluminium. Aluminium (56):165/168

2.2 Manufacturing process of 6xxx grades

Condition of the alloy elements Si + Mg characterize the material temper



- $\alpha_{supersaturated}$ → Cluster → Mg, Si Co-Cluster → GP1 zones → β'' (GP2 zones) → β' → β (Mg_2Si)

2.3 Lab trial

Target window

Primary goal: High electric conductivity

Secondary goal: Good processability within customer's production process

Property target window in coordination with customer needs:

- Conductivity
  ≥ 55,2 %IACS (International Annealed Copper Standard)
  ≥ 32 MS/m
- Yield strength ≥ 155 MPa
- Bending angle according ASTM E290 ≥ 135°

2.3 Lab trial

Parameter chemistry and T7 annealing

Test plan:

- Using two slightly different alloy A and alloy B in lab scale
- Findings are implemented in alloy C on a production scale

Chemistry EN AW-6101:

	Si [wt.%]	Fe [wt.%]	Cu [wt.%]	Mn [wt.%]	Mg [wt.%]	Cr [wt.%]	Zn [wt.%]	Al [wt.%]
min.	0.30				0.35			Residue
max.	0.70	0.50	0.10	0.03	0.80	0.03	0.10	

- Mn content alloy A > Mn content alloy B

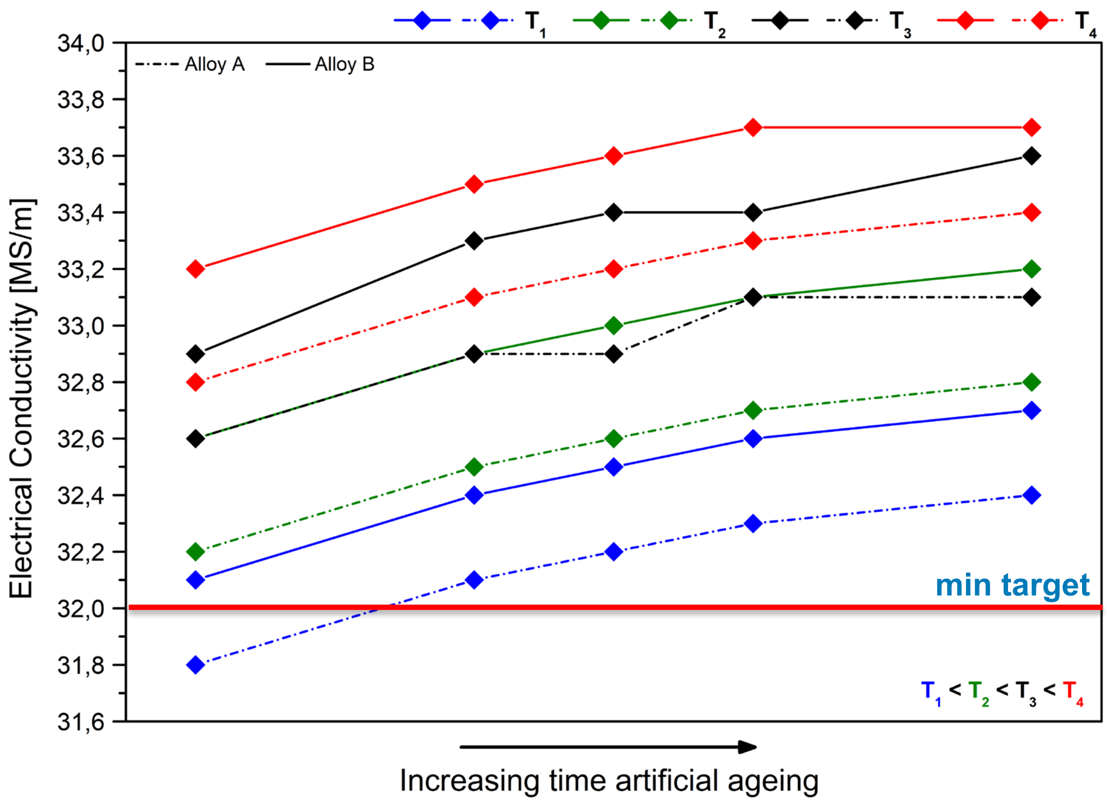
T7 annealing:

- Annealing matrix with four temperatures and five different holding times
- 20 annealing variants

3 Results and discussion

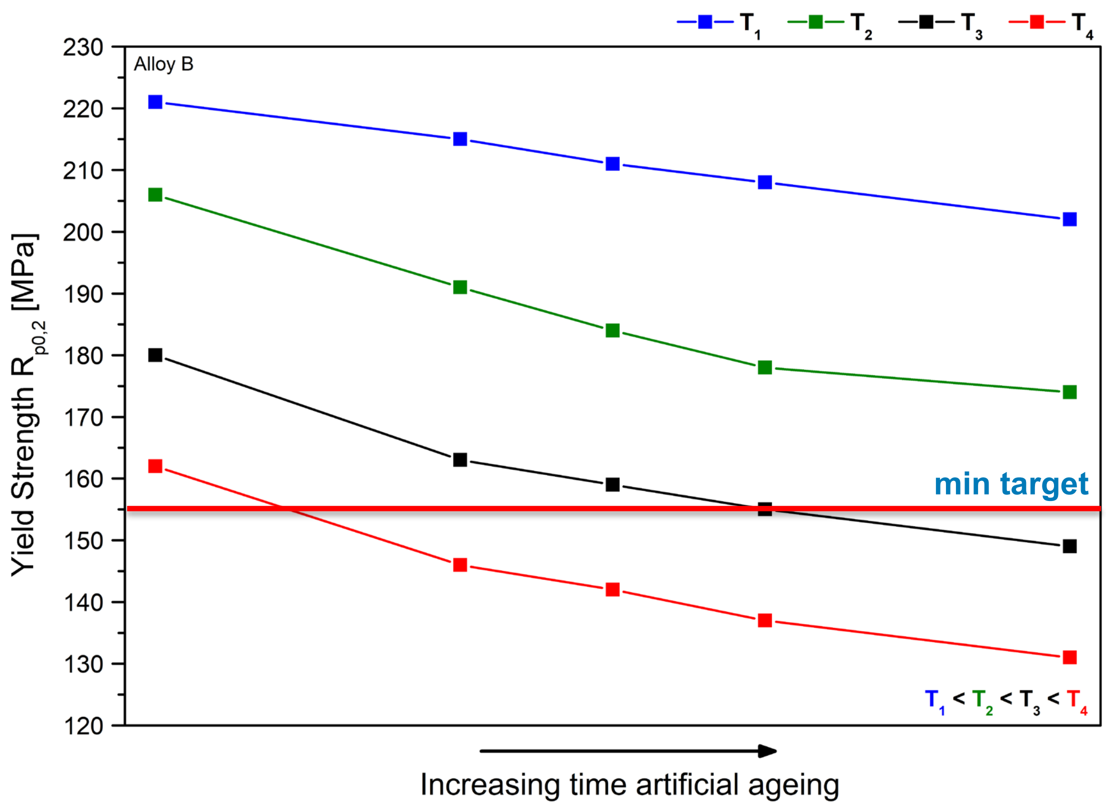
3 Results and discussion

Electric conductivity – significant higher at alloy B



3 Results and discussion

Yield Strength



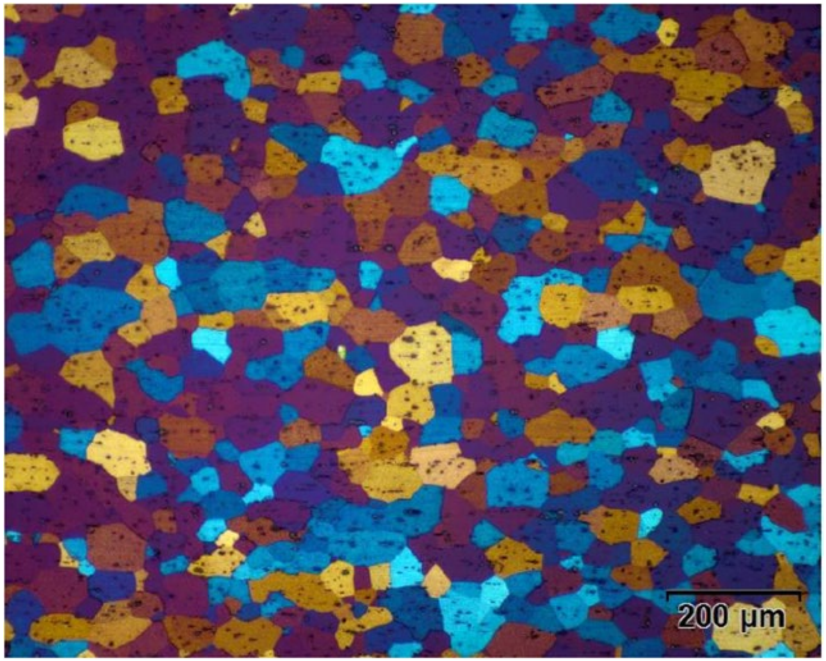
3 Results and discussion

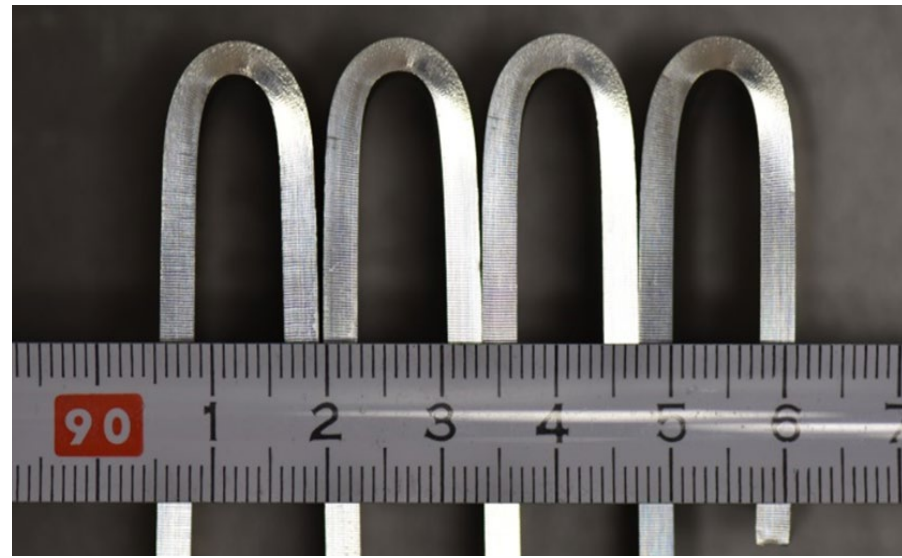
Transformation in the production process

- Additional reduction of the Mn content for production trial in improved alloy C
- Adjustment of the solution heat treatment process to the goals of the new alloy
- Evaluation of different heating rates between lab tests and production processes for T7 annealing

3 Results and discussion

Testing workability of the material





- Even and slightly grown grain structure with excellent bending performance
- ASTM E290 with banding radius factor N = 1

4 Conclusion

4 Conclusion

Real challenger for copper in electrically conductive applications

- Chemical composition and the over-aging heat treatment are decisive for generating the necessary mechanical properties

In summary, the new 6xxx Al-Mg-Si alloy achieves the following material properties:

- Electrical conductivity up to 58,1 %IACS (33,7 MS/m),
- Minimum yield strength of 150 MPa,
- Globular grain size of 50 µm,
- Bendability of 180° according to ASTM290 (radius N=1).

4 Conclusion

AMAG AL4® 6ZO – Zero Ohm

MECHANICAL PROPERTIES

As delivered in T7: Typical mechanical properties in transverse direction in gauge 3.0 mm.

$Rp_{0.2}$ [MPa]	Rm [MPa]	$R_{P0.2}/R_m$	A_g [%]	A_{50} [%]	σ [MS/m]
155	190	0,82	6	13	33,7

Bending capability: With the bending radius factor (N) = 1, the bending radius of 180° is successful for the gauge 3.0 mm according to ASTM E290.

- Material currently in various OEM trials
- Equipment capability up to thickness of 8 mm in coil

Thank you very much for you attention!