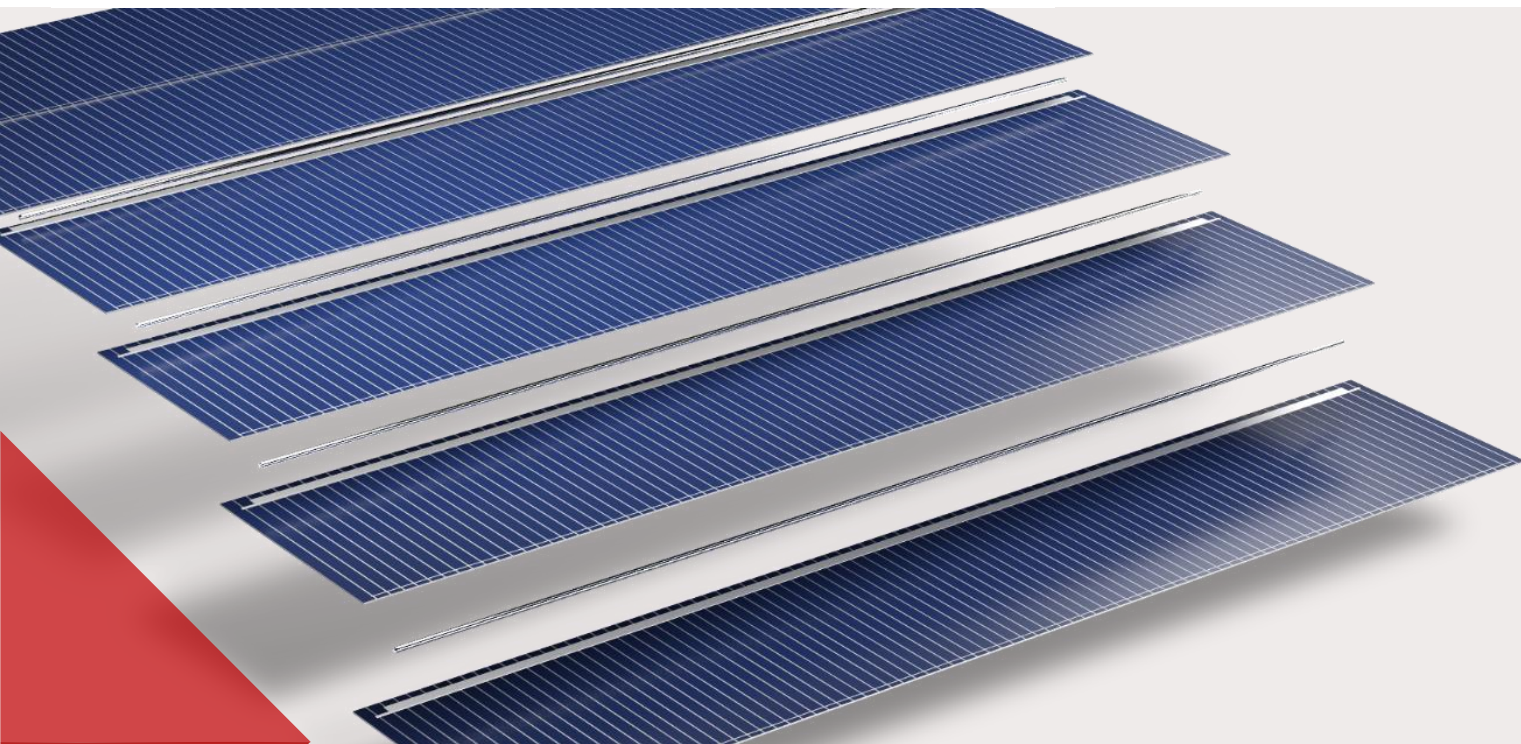




ENABLING SUSTAINABLE PV PRODUCTION WITH LOW-TEMPERATURE SNAP CURABLE ELECTRICALLY CONDUCTIVE ADHESIVES

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AGENDA

01 Henkel at a glance

02 ECAs in Solar

03 Sustainability at Henkel

HENKEL - A COMPELLING **PORTFOLIO** WITH ICONIC BRANDS...

HENKEL GROUP

ADHESIVE TECHNOLOGIES

LOCTITE

€3.3bn sales



TECHNOMELT

€1.6bn sales



>75%

Sales share of our 5 brand clusters for industrial customers & 4 key brands for consumers

CONSUMER BRANDS

Persil

€1.4bn sales



Schwarzkopf

€1.4bn sales



>50%

Top 10 brand sales share

SERVING **BROAD RANGE OF INDUSTRIES** ALONG THREE BUSINESS AREAS



MOBILITY & ELECTRONICS

Automotive OEMs & components,
e-mobility, metal coil, electronics,
semiconductor packaging,
aerospace, industrial assembly,
power & **Solar**

#1 WORLDWIDE



PACKAGING & CONSUMER GOODS

Food & beverage, hygiene,
metal and flexible packaging,
sports & fashion

#1 WORLDWIDE

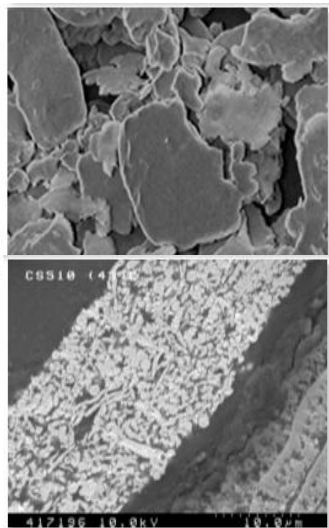


CRAFTSMEN, CONSTRUCTION & PROFESSIONAL

DIY, craftsmen, construction,
engineered wood, professional
users in manufacturing &
maintenance

#3 WORLDWIDE

► ELECTRICALLY CONDUCTIVE ADHESIVES (ECAS) DEVELOPMENT OVERVIEW



Cross section of an ECA bond

ECA Technology

Conductive filler package

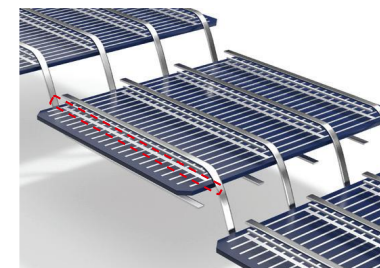
- Bulk and contact resistivity
- Current capacity
- Percolation threshold
- Rheology
- Reliability performance

Polymer resin

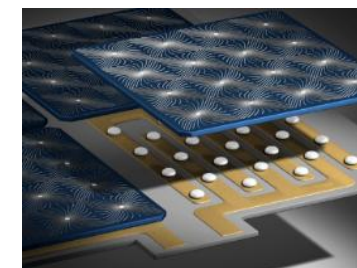
- Cure speed
- Adhesion
- Reliability performance
- Work life

Interconnection type

Ribbon attach



Back contact



Cell type

c-Si, PERC, HJT

IBC, MWT

Products Qualified

CA 3556HF, **ICP 8311**
ICP 8282

3104WXL, **3103WLV**,
ICP 3535M2

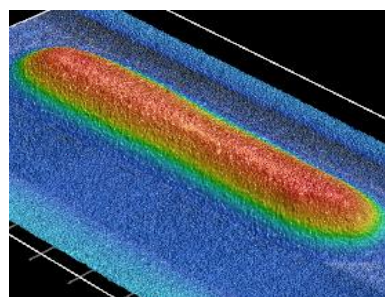
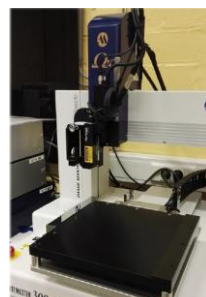
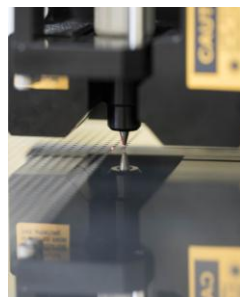
Chemistry

Acrylate

Epoxy

ECA application technique

- Printing: screen and stencil
 - Dispensing
 - Jetting
- Focus on fast throughput



Developments on emerging technologies

Perovskite technology as a growing market

- Reduced thermal budget
- Low temperature curing adhesives (optimally below 120 °C)

ECAs with improved non-noble compatibilities

- Reduced total cost of ownership

▶ ELECTRICALLY CONDUCTIVE ADHESIVES

VALUE PROPOSITION

Value Proposition



Cost Reduction

- Electrically conductive adhesives (ECAs) using advanced filler technology to **minimize silver content and material density**.
- ECAs containing anti-corrosion technology, enabling use of **non-noble metallization**.
- Flexible ECAs with low temperature cure profile **reduces energy consumption** in production



Sustainability

- **Low temperature** cure ECAs allow use of temperature sensitive components and substrates
- Low temperature and **fast cure** ECAs enable a reduced energy consumption footprint
- Improved H&S labeling (non CMR)
- Enabling **higher** module **power**, **reduced Ag** and **usage** -> more **CO₂ savings**



Improved reliability

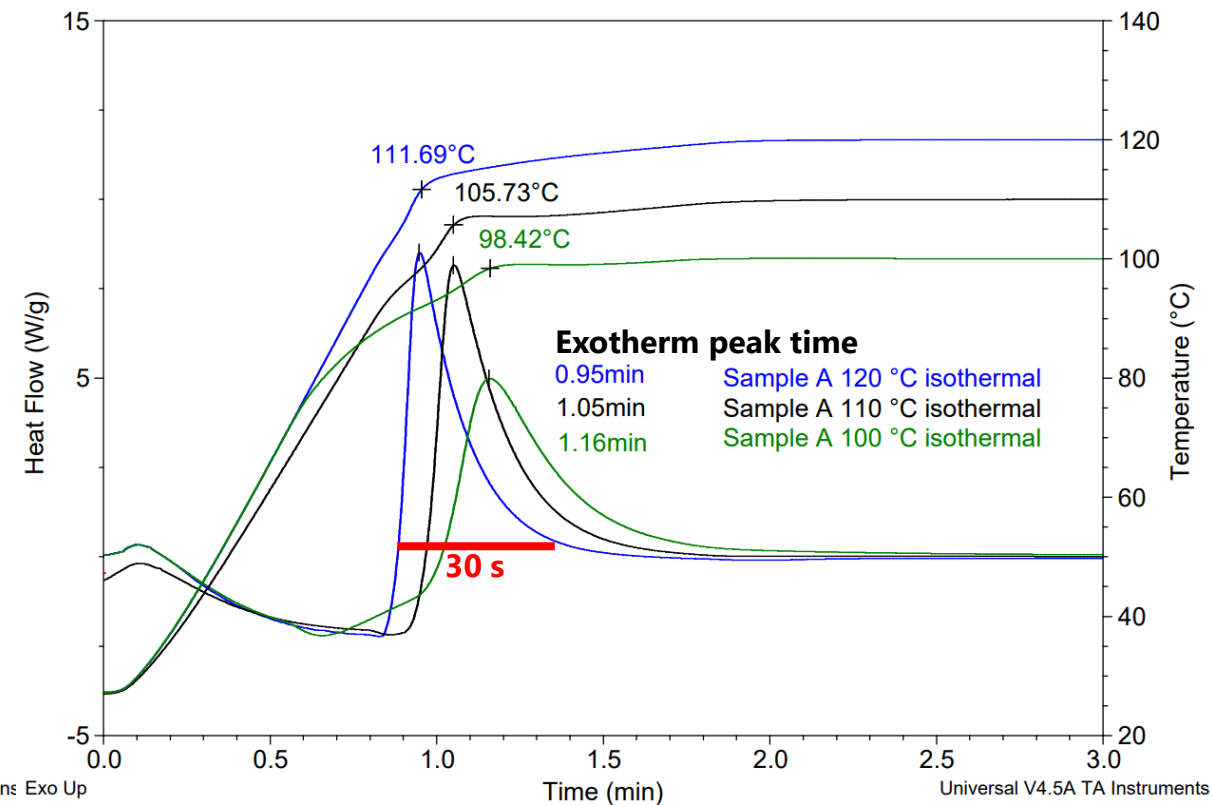
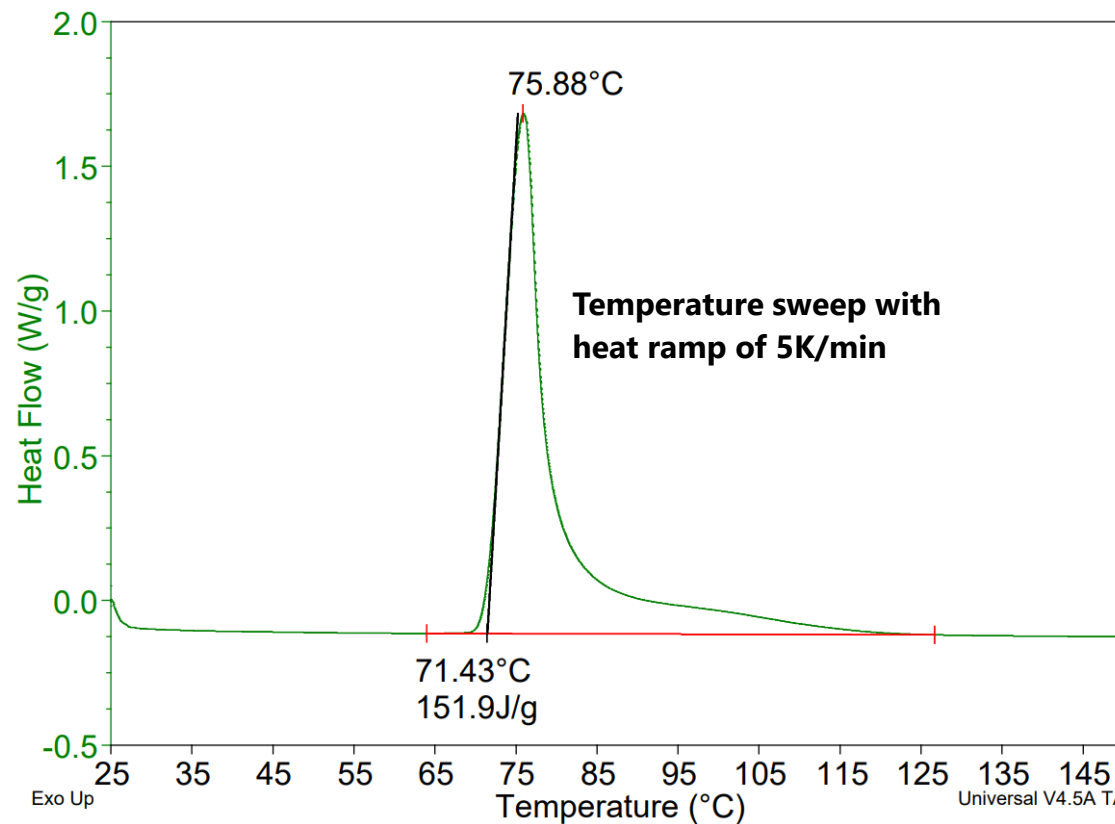
- ECAs that can cope with the **increasing reliability** demands from the industry
- ECAs with high current capabilities and heat dissipation
- ECAs with improved high temperature adhesion



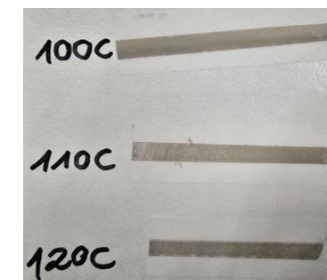
Miniaturization 3D integration

- ECAs with focus on small feature/printing and high throughput.

► CURE TIME EVALUATION OF ECAS



- Cure time evaluation via DSC → cure starts below 75 °C (left graph), full cure in 30s during 120 °C ramp (right graph)
- Glass slide samples exhibit surface tackiness after curing 30s at 120 °C on hot plate



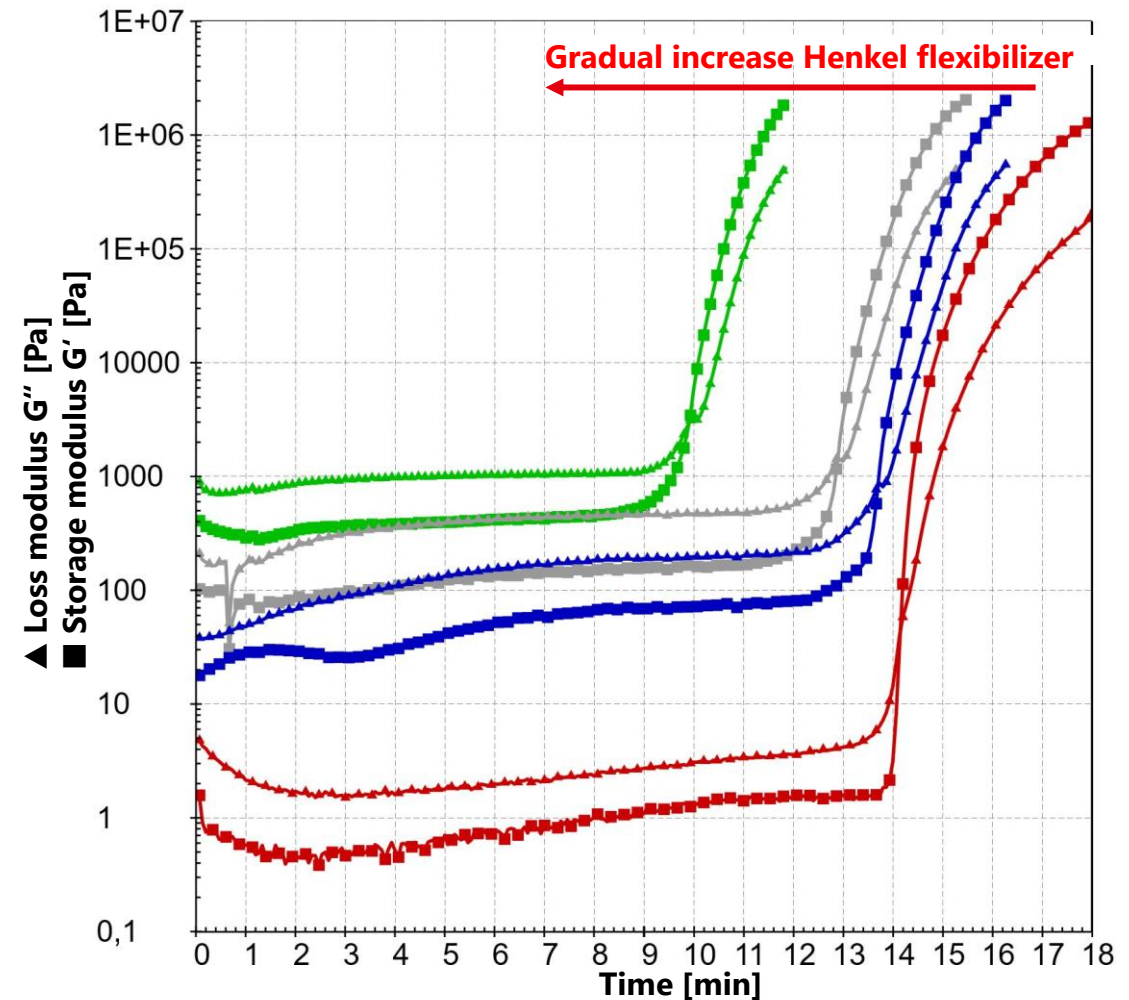
► TACK-FREE ECA DEVELOPMENT

- Tack-free samples when curing under nitrogen atmosphere
→ surface oxygen inhibition
- Gel time as alternative to determine cure speed
- Development of **oxygen scavenging flexibilizer** (Henkel patent)
- Replacing standard flexibilizer results in reduced gel times , as well as reduction of tackiness



Tack-free samples after 20s at 120 °C

Gel time cure speed evaluation at 60°C



SUSTAINABILITY @HENKEL ADHESIVE TECHNOLOGIES

Leading by **EXAMPLE**

SUSTAINABLE OPERATIONS

19 carbon neutral plants & 96% Renewable Electricity
SBTi Net Zero Target 2045 (incl. Scope 3)

SUSTAINABLE PRODUCTS

Supporting suppliers to reduce process emissions (e.g. Recycled silvers)

SUSTAINABILITY INTELLIGENCE

Providing transparency on our product carbon footprint

Leading through **TECHNOLOGY**

ENABLING SUSTAINABILITY



LOWERING EMISSIONS IN CUSTOMER PROCESSES & PRODUCT USE PHASE



ENABLING REUSE, REPAIR & REFURBISH



ENHANCING SAFETY AT CUSTOMER PROCESSES



REDUCING WATER & IMPROVING WASTEWATER QUALITY

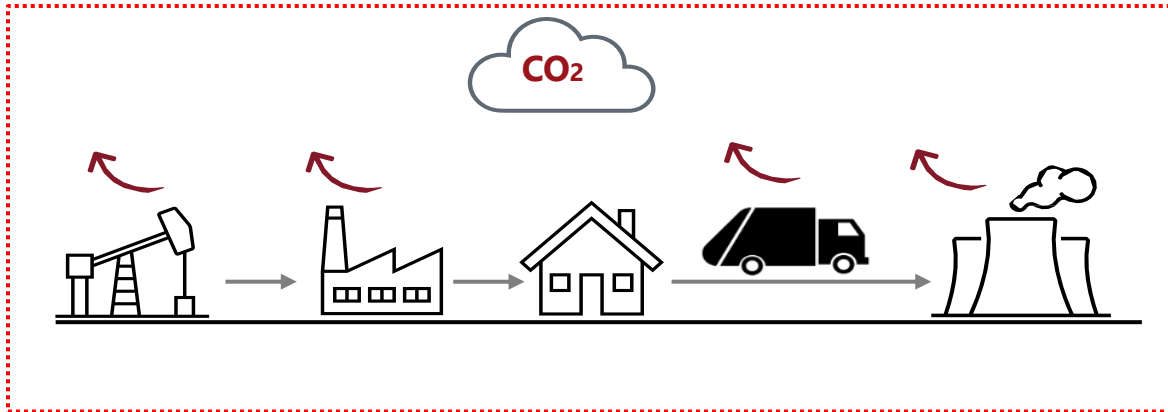


► ECA GRADLE-TO-GATE CASE STUDY

1) Full silver, low silver and new filler technology

2) Curing schedules

3) Volume savings through density



FORMULATION



PRODUCTION



PACKAGING



TRANSPORTATION

3. **Functional Unit (FU):** 1 kg

- Scenario 1: Full silver ECA (high silver loading 85 wt% Ag)
- Scenario 2: Low silver ECA (50-55 wt% Ag)
- Scenario 3: New Filler technology ECA (25-35 wt% Ag)

4. **System Boundaries:** Cradle-to-Gate and Downstream transportation

- Formulation
- Production technologies
- Packaging
- Upstream transportation
- Downstream transportation

5. **Impact categories:** GWP100 [kg CO₂-eq]

6. **Geographic boundaries:** Global Market

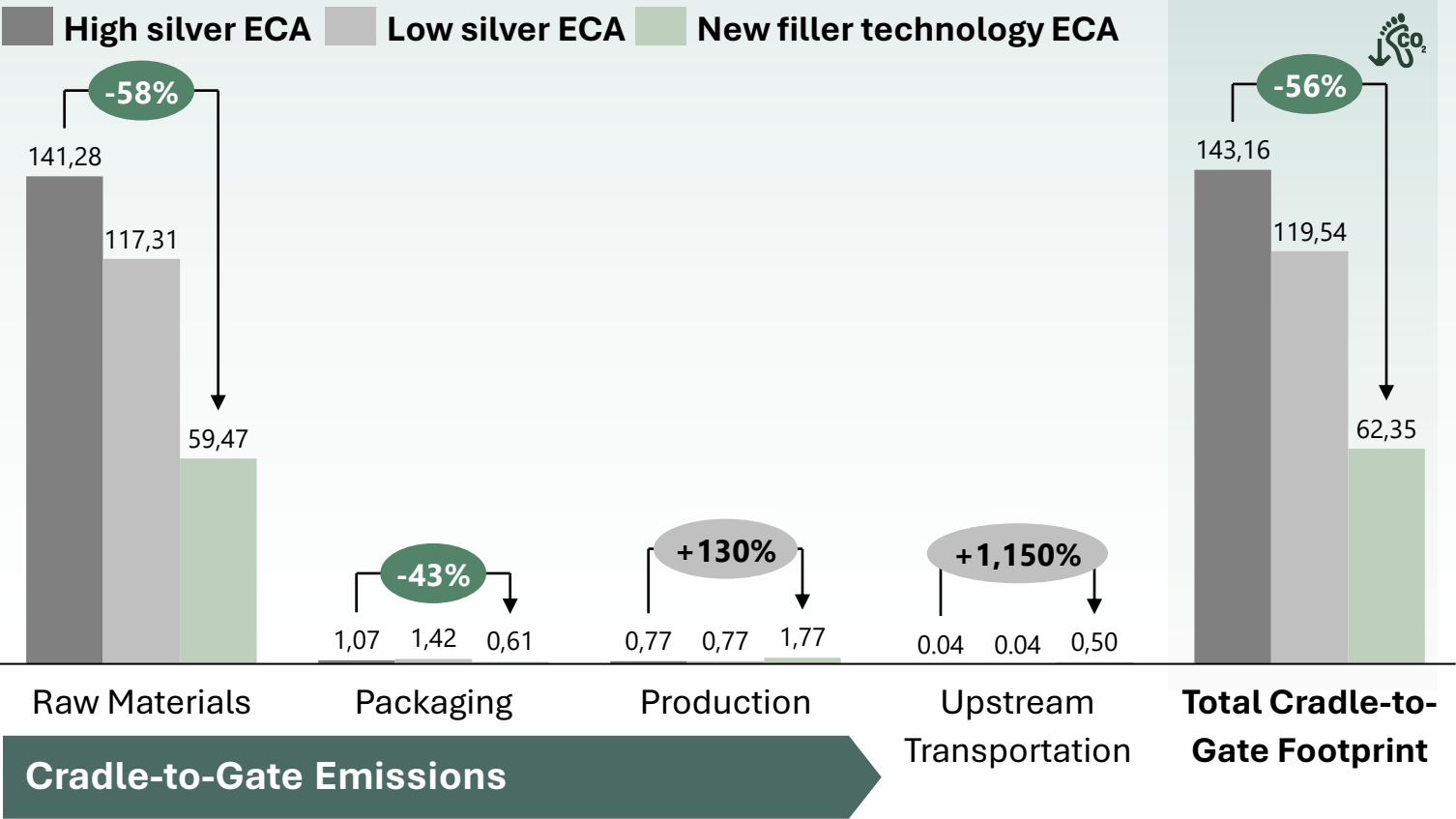
7. **Emission factor data sources:** BF 2.0/ Supplier values/ Ecoinvent 3.10

8. **Standard:** ISO 14040-44

9. **Analysis tool:** Internal Analysis, EF 3.1

EMISSIONS SAVINGS: *CRADLE-TO-GATE*

Unit: kg CO₂ per kg product



> Cradle-to-gate emissions are **up to 56% lower** for new filler technology ECA



THANK YOU!