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INNOVATION
AMG Business Segments

AMG Critical Materials

AMG’s conversion, mining, and recycling businesses
- Vanadium
- Superalloys
- Titanium Alloys & Coatings
- Aluminum Alloys
- Tantalum & Niobium
- Antimony
- Graphite
- Silicon

AMG Engineering

AMG’s vacuum systems and services business
- Engineering
- Heat treatment services
AMG Global Footprint – Critical Materials

- China
- Sri Lanka
- Zimbabwe
- Brazil
- U.S.A.
- Mexico
- France
- German
- Czech Republic
- China
- Sri Lanka
- Mozambique
- Zimbabwe

Critical Materials:
- Chromium (Cr)
- Antimony (Sb)
- Carbon (C)
- Silicon (Si)
- Titanium (Ti)
- Aluminum (Al)
- Vanadium (V)
- Tantalum (Ta)
- Niobium (Nb)
- Nickel (Ni)
- Molybdenum (Mo)

AMG Global Master Alloys, Aluminum Powders, Alloys & Coatings
Utilizing its team of twelve specialty metallurgists and scientists together with years of research and development, AMG developed a high purity natural graphite product which is used in insulation materials and improves the insulating performance by up to 20 percent.

The natural graphite in this insulation reflect solar and heat radiation.

- This saves heating costs and enhances the value of buildings in an environmentally friendly way.
- This next generation insulation material provides more space and comfort in high energy-efficient houses and buildings.

Source: Management estimates
AMG Graphite – Mining Operations

- Kropfmühl, Germany
- Lynx, Zimbabwe
- Ancuabe & Nipacue, Mozambique
- Bogala, Sri Lanka
- Germany
- Sri Lanka
- Zimbabwe
- Mozambique
- China

▲ Mining facilities
AMG Vanadium – Cambridge, Ohio Site
AMG Engineering – Turbine Blade Coater
AMG Engineering – Global Installed Base

Asia > ~ 660 systems installed 
Europe > ~ 750 systems installed 
North America > ~ 150 systems installed

Note: Shaded countries represent ALD’s countries of presence; Systems installed is based on the number of installed furnaces until March 2013
SUSTAINABILITY
The Global Environmental Challenge

RECENT MONTHLY MEAN CO₂ AT MAUNA LOA

Monthly mean
Adjusted for seasonal cycle

Source: Management estimates
Sustainability Understanding

\[ \text{CO}_2 = \text{Population} \times \text{Affluence} \times \text{Technology} \]

\[ \text{CO}_2 = P \times \left( \frac{\text{E}}{\text{GDP}} \right) \times (\text{E per capita}) \times (\text{CO}_2 \text{ per E}) \]

Technologies Required to Decrease: \( T_1 + T_2 + T_3 \)

- \( T_1 = \) Industrial Mitigating Technologies
- \( T_2 = \) Transportation
- \( T_3 = \) Buildings

\( P = \) Population
\( E = \) Energy Consumption

Source: Management estimates
USA Energy Consumption by End Use Sector

INNOVATION & SUSTAINABILITY
Mitigating Technologies – Ferrovanadium Alloy Manufacture

**Base Technology**

Primary Mining and Processing‡

| CO₂/lb V | 28.2 kg |

**Enhanced Technology**

Spent Refinery Catalyst Recycling

| CO₂/lb V | 13.7 kg |

Presently about 5.6 Million lbs of Alloyed Vanadium Per Year

Mitigates App. 81,000 mt CO₂ Emissions per Year

‡ GaBi 6 reference number for 80% FeV converted to equivalent for 65% FeV

Source: Management estimates
Enabling Technologies – Graphite Based Insulation

Base Technology
No Insulation

Enhanced Technology
Graphite Enhanced EPS Insulation

GRAPHITE ENHANCED EXPANDED POLYSTYRENE INSULATION
Increases Thermal Coefficient of the Insulating Materials
Estimated CO2 savings are 5,913 kg per standard family home per year

Estimated CO₂ Savings, 5,913 kg per home per year
From 2010 to end 2013 AMG has supplied 30,000 mt of graphite, enough to produce insulation for approximately 790,000 homes

2014 Enabled CO₂ Savings 4.7 million mt

Source: Management estimates
In 2011 2.8 Billion Passengers Travelled by Air and Aircraft emitted 676 million mt of CO$_2$

Enables App. 800,000 mt CO$_2$ Savings per Year$^1$

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### Enabling Technologies – Heat Treatment of Transmissions

<table>
<thead>
<tr>
<th>Technology</th>
<th>4 Speed Transmission</th>
<th>6 Speed Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>CO₂/km</strong></td>
<td>200g</td>
</tr>
<tr>
<td>Base Technology</td>
<td></td>
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**VACUUM SURFACE HARDENING**

To enable cost efficient manufacturing of high quality components for modern fuel saving transmissions with more gears, handling higher torques at lower weight.

1.7 Million Transmissions Per Year (2014)

From 2010 to end 2013 AMG has vacuum surface hardened 7.8 million transmissions

2014 Enabled CO₂ Savings 2.2 million mt

---

1 Average savings estimated at 20,000 km and 280 kg CO₂ per vehicle per year, North American Vehicle Market
### Enabling Technologies – Heat Treatment of Fuel Injectors

**Base Technology**

<table>
<thead>
<tr>
<th>1.2 Gasoline</th>
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<tbody>
<tr>
<td>Power</td>
<td>77 kW</td>
</tr>
<tr>
<td>Pressure</td>
<td><strong>150 bar</strong></td>
</tr>
<tr>
<td>CO₂/km</td>
<td>134g</td>
</tr>
<tr>
<td>CO₂/year</td>
<td>2,680kg</td>
</tr>
</tbody>
</table>

**Enhanced Technology**

<table>
<thead>
<tr>
<th>1.6 Diesel</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Power</td>
<td>77 kW</td>
</tr>
<tr>
<td>Pressure</td>
<td><strong>2,250 bar</strong></td>
</tr>
<tr>
<td>CO₂/km</td>
<td>119g</td>
</tr>
<tr>
<td>CO₂/year</td>
<td>2,380kg</td>
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</table>

**VACUUM SURFACE HARDENING**
for common rail diesel fuel injectors to operate under higher pressures

10.8 Million Units → 2.7 Million Vehicles (2014)

From 2010 to end 2013 AMG has vacuum surface hardened diesel fuel injectors for 11.5 million vehicles

**2014 Enabled CO₂ Savings 4.9 million mt**

*Average savings estimated at 20,000 km and 350 kg CO₂ per vehicle per year*
Enabling Technologies – Aerospace Titanium Alloys

In 2011 2.8 Billion Passengers Travelled by Air and Aircraft emitted 676 million mt of CO₂

1% weight saving Enables App. 5,000,000 mt CO₂ Savings per Year

1 1% weight saving results in approximately 0.75% fuel savings.
2 The 787-800 achieves fuel savings through use of composites and titanium and engine and aerodynamic improvement.
Enabling Technologies – Vehicle Light Weighting

Base Technology
Steel Vehicle Panels

Enhanced Technology
Aluminum Vehicle Panels

ENABLING TECHNOLOGY

GRAIN REFINERS FOR ALUMINUM IN VEHICLE PANELS
Series 5xxx, 6xxx and 7xxx (Military Grade) aluminum alloys utilized in new vehicles reduce weight and increase fuel efficiency

New 2015 Ford F-150 – estimated 520,000 units per year
Improved fuel efficiency estimated at 20% (from 18 to 21 mpg)

Potential 685,000 mt CO₂ Savings per Year

Source: Management estimates
Enabling Technologies – Gamma Titanium Aluminides

Base Technology
Current Technology
Aircraft Engine

Enhanced Technology
Gamma Titanium Aluminide

A320 NEO / B737 MAX

ENABLING TECHNOLOGY

Gamma Titanium Aluminide Engine Components
Reduced weight of turbine blades dramatically increasing efficiency
Estimated fuel saving is 15% over current technology

Estimated new fleet – 2014 to 2035
A320 NEO, B737 MAX, B747 and B787 – 21,320 Aircraft\(^1\)

Potential 76 million mt CO\(_2\) Savings per Year by 2035\(^2\)

\(^1\) Source: Airline Monitor, February 2012
\(^2\) Website MTU Aero Engines
AMG’s CO2 Reduction Contributions - Enabling

- **Cumulative reduction of CO₂ due to AMG enabling technologies**
  - Benefits from ‘enabling’ technologies are cumulative and remain throughout the lifetime of the product

- **Example – Ford F150 Light Weighting**
  - Assumptions – production volume 520,000 per year
  - Lifespan of truck, 150,000 miles (11 years)
  - 21 mpg to 18 mpg improvement

![Graph showing cumulative effects of CO₂ emissions reduction](chart.png)

**10 YEAR CUMULATIVE EFFECTS ON CO₂ EMISSIONS vs BASELINE YEAR**
37.6 million metric tons

**520 thousand vehicles in use**

**5.2 million vehicles in use**

Source: Management estimates
Enabling Technologies Summary

Source: Management estimates
Enabling Technologies: 2015 vs. 2025

Amounts reflect cumulative CO$_2$e reductions in millions of metric tons

Source: Management estimates