



Innovation Conference

A-P Foundation

Mainz

Friday, October 23, 2015

“Innovation and Sustainability”

Dr. Heinz Schimmelbusch

A nighttime photograph of a city skyline with a prominent multi-level highway interchange in the foreground. The city is illuminated with various lights, and the sky is a deep blue. The highway has long-exposure light trails from cars, creating a sense of motion. The city buildings in the background are lit up, showing a dense urban environment.

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INNOVATION

AMG Business Segments

AMG Critical Materials

AMG's conversion, mining, and recycling businesses

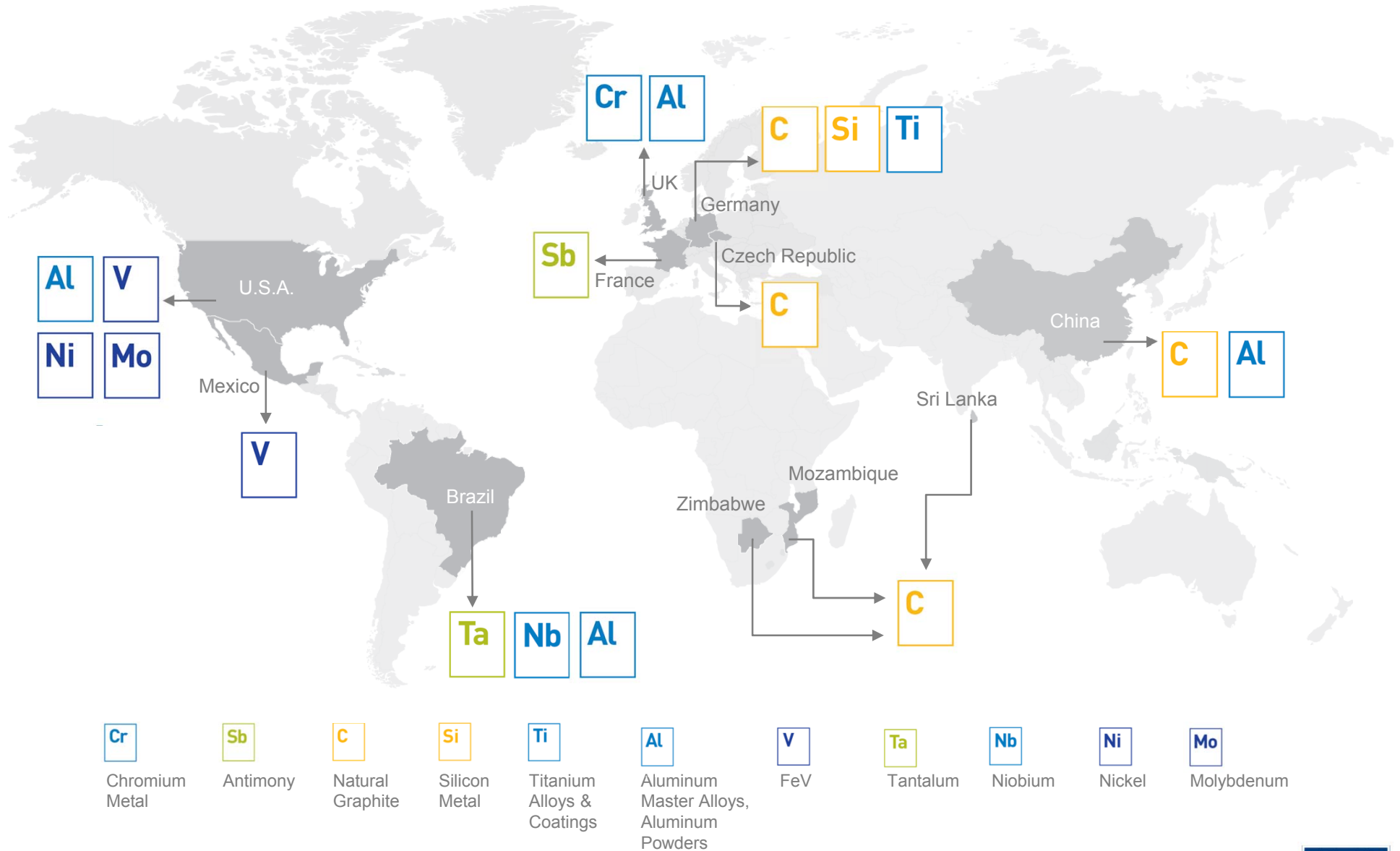
- Vanadium
- Superalloys
- Titanium Alloys & Coatings
- Aluminum Alloys
- Tantalum & Niobium
- Antimony
- Graphite
- Silicon

AMG Engineering

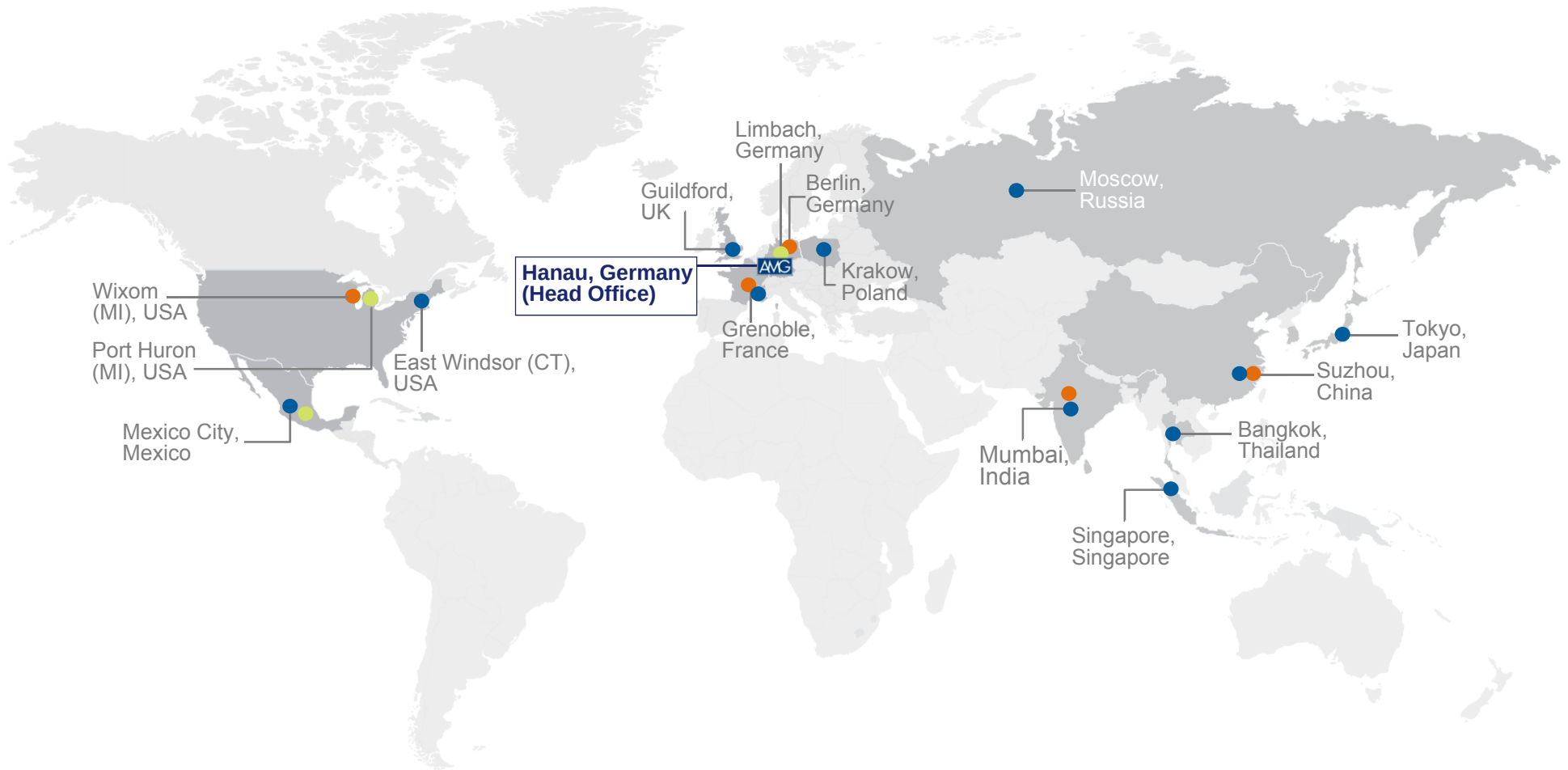
AMG's vacuum systems and services business

- Engineering
- Heat treatment services

AMG Global Footprint – Critical Materials



AMG Global Footprint – Engineering



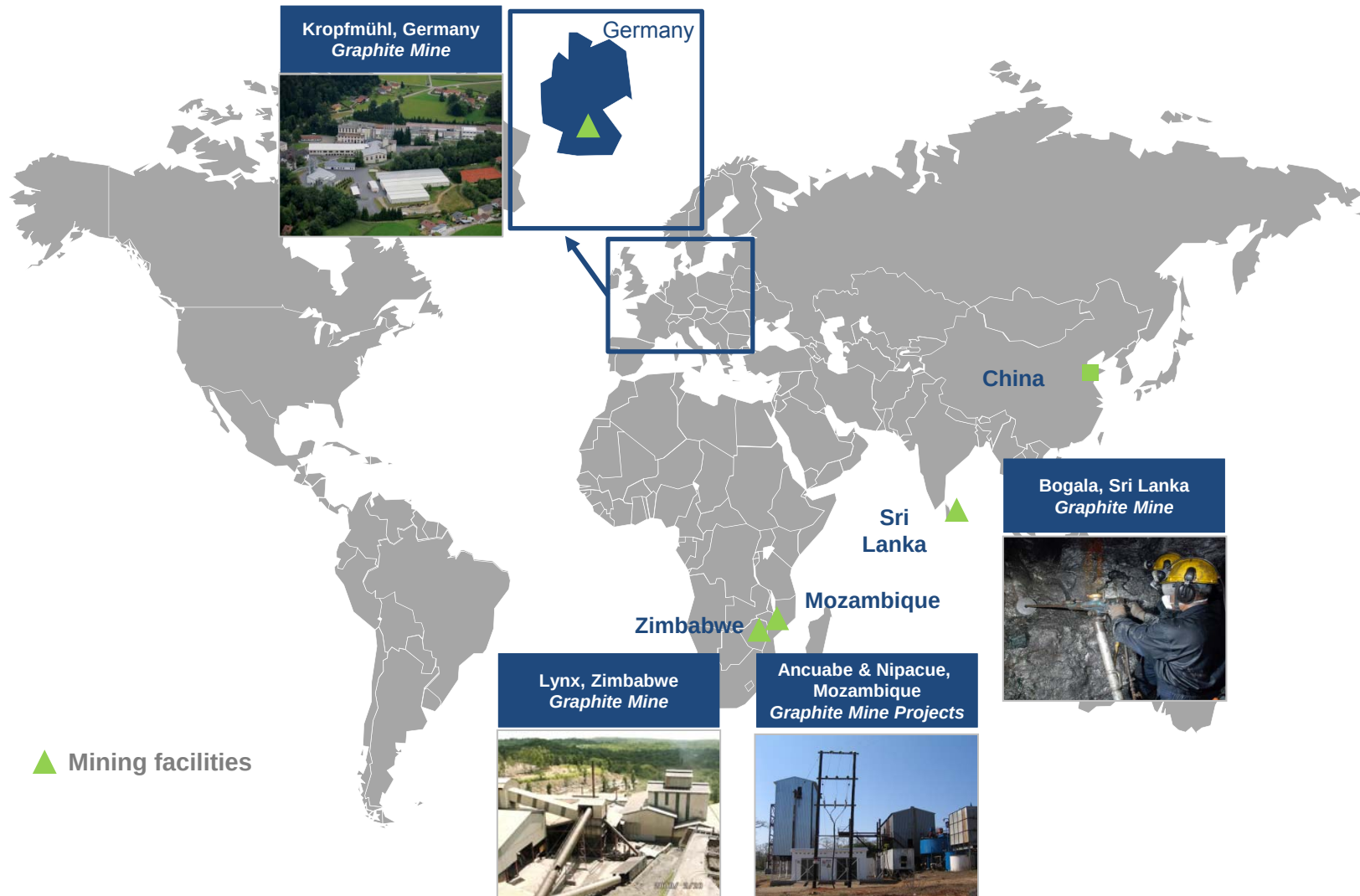
 Headquarters ● Sales office ● Production Facility ● Heat Treatment Services

AMG Graphite – Insulation Materials

- 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.



AMG Graphite – Mining Operations



AMG Vanadium – Cambridge, Ohio Site

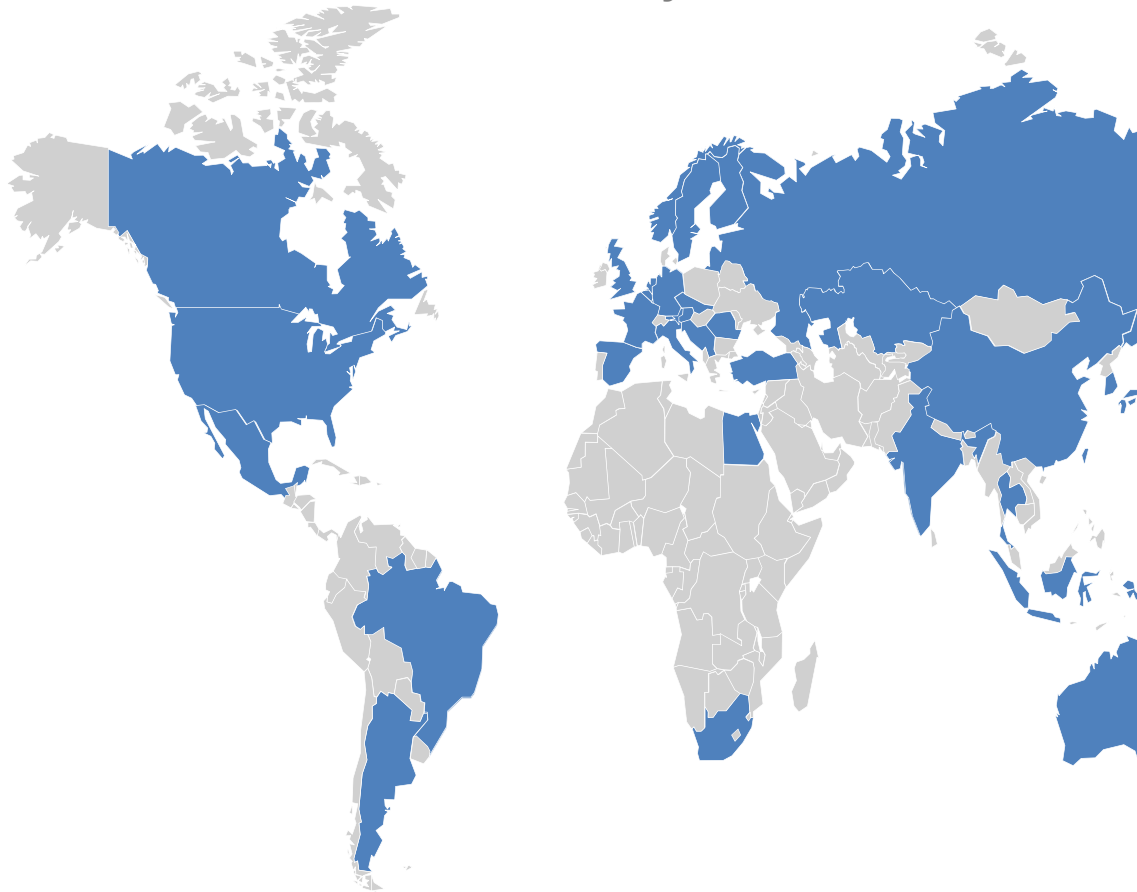


AMG Engineering – Turbine Blade Coater



AMG Engineering – Global Installed Base

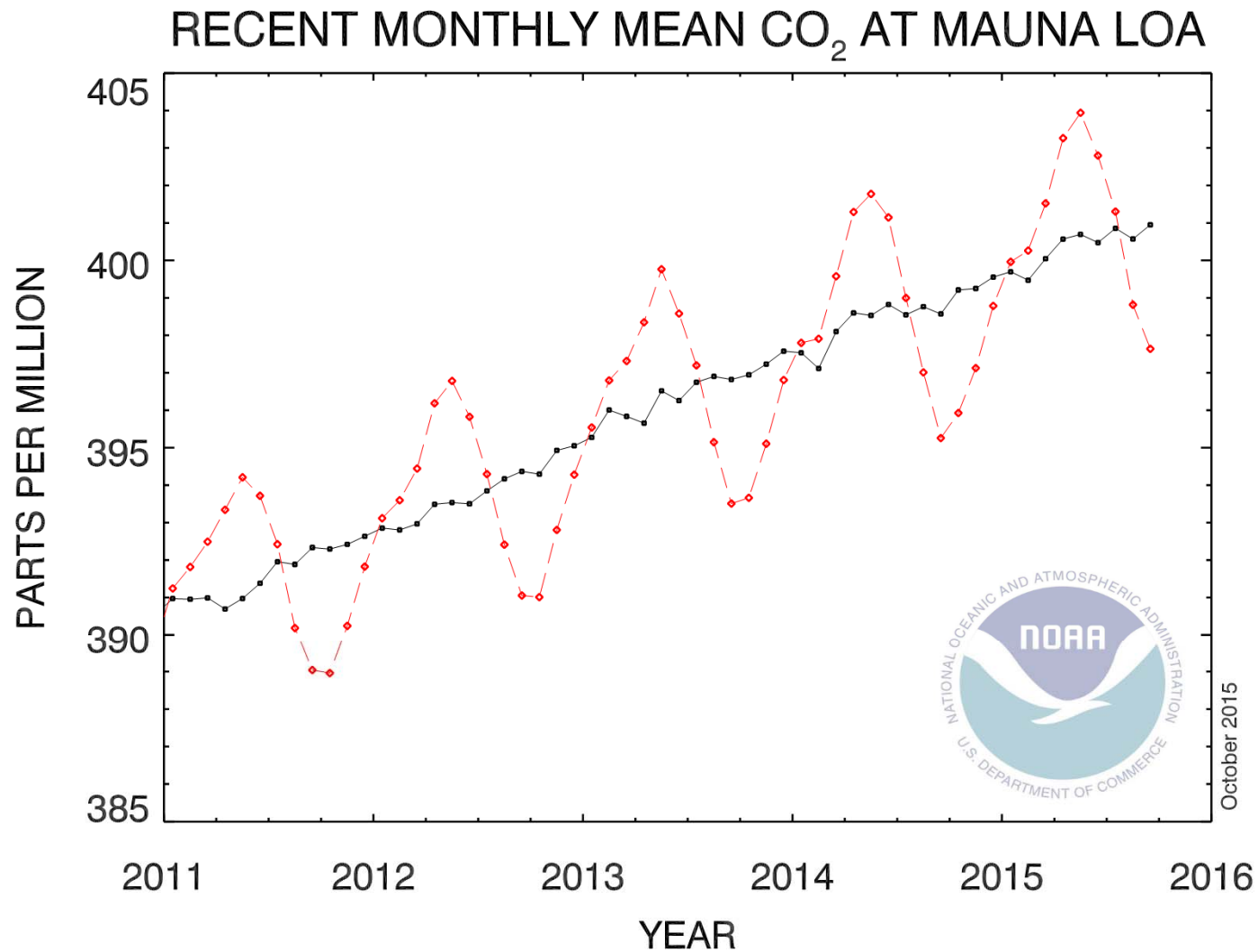
Asia > ~ 660 systems installed
 Europe > ~ 750 systems installed
 North America > ~ 150 systems installed



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



Monthly mean
Adjusted for seasonal cycle

Source: Management estimates

Sustainability Understanding

$$\text{CO}_2 = \text{Population} * \text{Affluence} * \text{Technology}$$

$$\text{CO}_2 = P * \underbrace{(\text{per capita GDP})}_{\text{Increasing}} * \underbrace{(\text{E per capita})}_{\text{Technologies Required to Decrease: } T_1+T_2+T_3} * (\text{CO}_2 \text{ per E})$$

Increasing

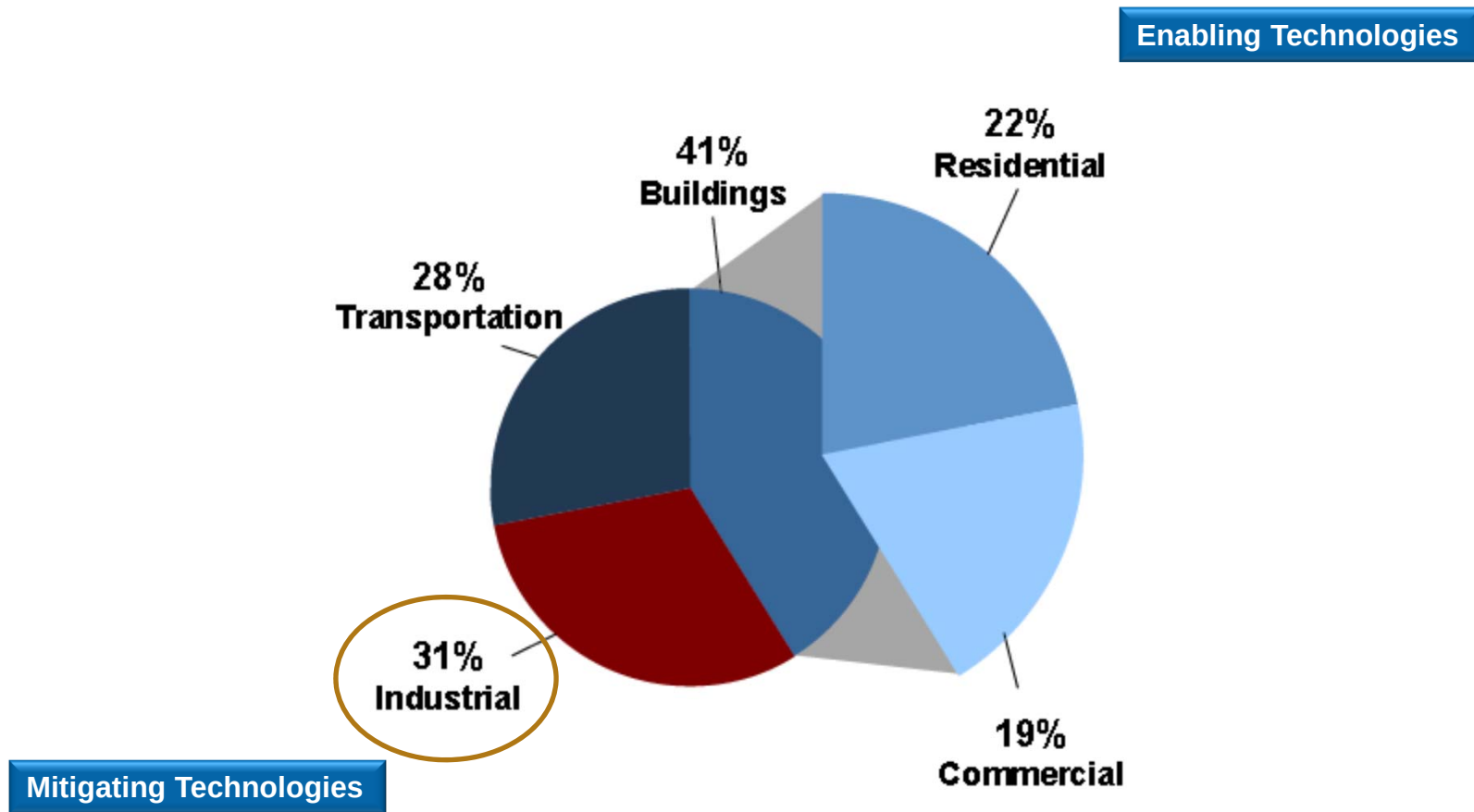
Technologies Required
to Decrease: $T_1+T_2+T_3$

T_1 = Industrial
Mitigating Technologies

T_2 = Transportation
 T_3 = Buildings
Enabling Technologies

P = Population
E = Energy Consumption

USA Energy Consumption by End Use Sector



INNOVATION & SUSTAINABILITY

Mitigating Technologies – Ferrovanadium Alloy Manufacture

Base Technology

Primary Mining and Processing[†]

CO ₂ /lb V	28.2 kg
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Enhanced Technology

Spent Refinery Catalyst Recycling

CO ₂ /lb V	13.7 kg
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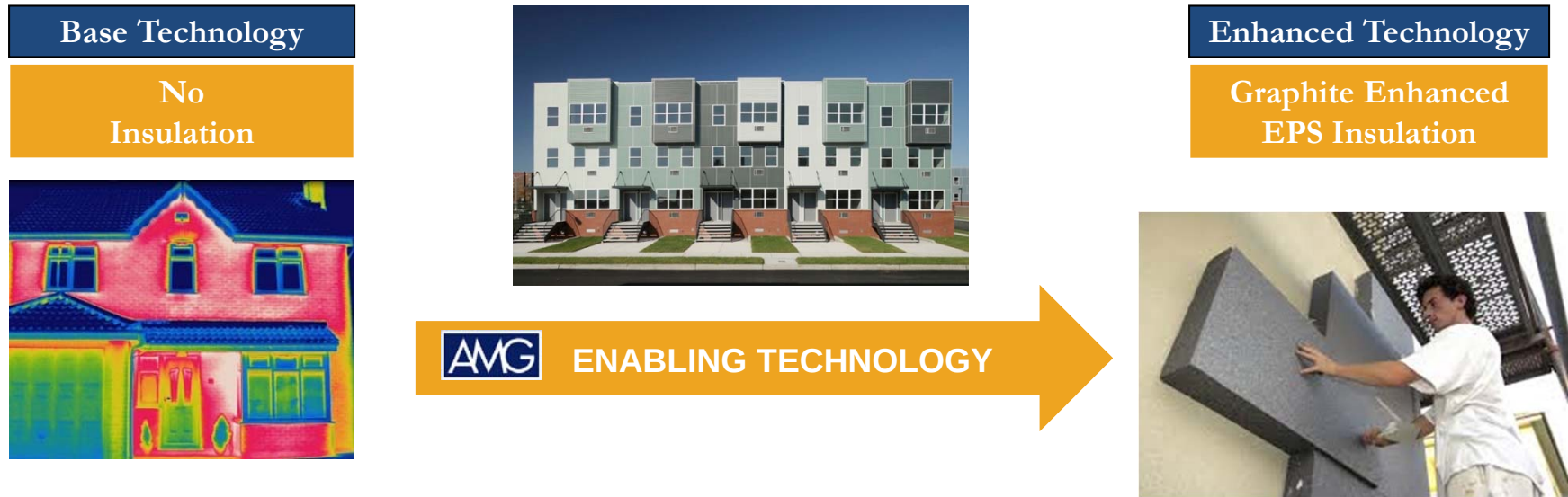
MITIGATING TECHNOLOGY

PYROMETALLURGICAL RECYCLING
Ferrovanadium is produced from oil refinery
wastes with no mining or raw material
beneficiation required

Presently about 5.6 Million lbs of Alloyed Vanadium Per Year

Mitigates App. 81,000 mt CO₂ Emissions per Year

Enabling Technologies – Graphite Based 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

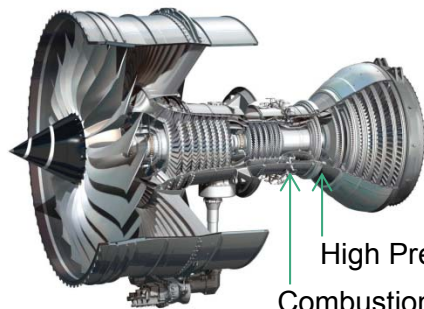
From 2010 to end 2013 AMG has supplied 30,000 mt of graphite,
enough to produce insulation for approximately 790,000 homes

2014 Enabled CO₂ Savings 4.7 million mt

Enabling Technologies – Aerospace Turbine Blade Coatings

Base Technology

Non TBC
Jet Engine



High Pressure
Combustion



ENABLING TECHNOLOGY

Enhanced Technology

TBC
Jet Engine



THERMAL BARRIER COATING (TBC)

Allow turbines to operate above the melting point of the construction alloy
Estimated Fuel Saving is 1%¹

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

Enables App. 800,000 mt CO₂ Savings per Year¹

Enabling Technologies – Heat Treatment of Transmissions

Base Technology

4 Speed Transmission

CO ₂ /km	200g
CO ₂ /year	4,280kg



Enhanced Technology

6 Speed Transmission

CO ₂ /km	186g
CO ₂ /year	4,000kg



ENABLING TECHNOLOGY

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

Enabling Technologies – Heat Treatment of Fuel Injectors

Base Technology	
1.2 Gasoline	
Power	77 kW
Pressure	150 bar
CO ₂ /km	134g
CO ₂ /year	2,680kg



ENABLING TECHNOLOGY

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

Enhanced Technology	
1.6 Diesel	
Power	77 kW
Pressure	2,250 bar
CO ₂ /km	119g
CO ₂ /year	2,380kg



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

Enabling Technologies – Aerospace Titanium Alloys

Base Technology

Airbus A319

CO ₂ Per passenger per km	97.5g
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ENABLING TECHNOLOGY

AIRFRAME WEIGHT REDUCTIONS
Replacement of steel with Ti Alloys
AMG has **25%** Market Share

Aircraft	Titanium Composition	Aircraft	Titanium Composition
Boeing 787	115 tons	Airbus A380	77 tons
Boeing 777	58 tons	Airbus A340	24 tons
Boeing 747	43 tons	Airbus A330	17 tons
Boeing 737	18 tons	Airbus A320	12 tons

Enhanced Technology

787-800²

CO ₂ Per passenger per km	75g
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The most Titanium intensive aircraft

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 Year¹

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



Aluminum Door Panel



ENABLING TECHNOLOGY

Enhanced Technology

Aluminum Vehicle Panels



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

Enabling Technologies – Gamma Titanium Aluminides

Base Technology

Current Technology Aircraft Engine



A320 NEO / B737 MAX



ENABLING TECHNOLOGY

Enhanced Technology

Gamma Titanium Aluminide



GE/SNECMA - LEAP
GE - GenX
P&W - GTF

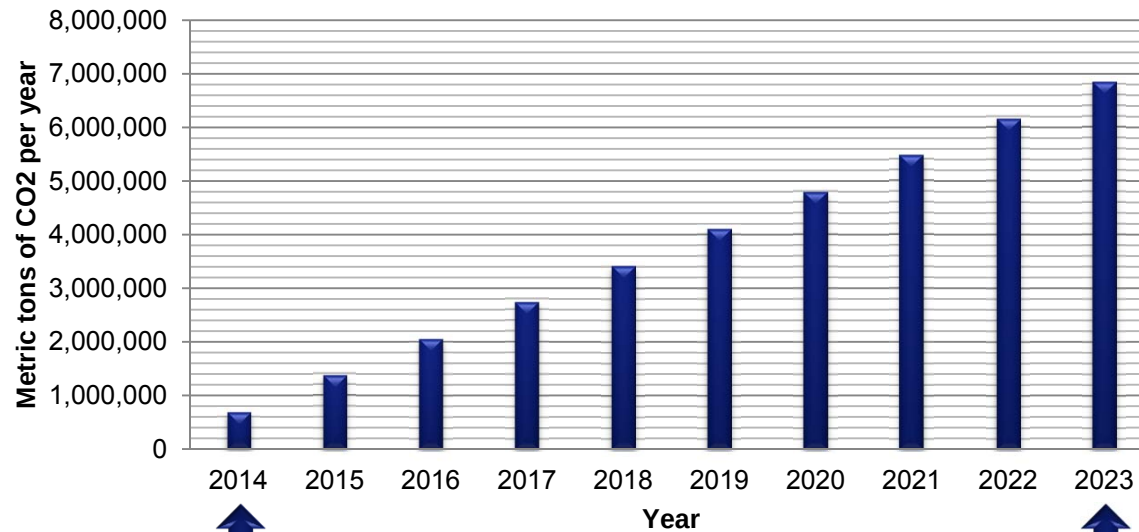
GAMMA TITANIUM ALUMINIDE ENGINE COMPONENTS
Reduced weight of turbine blades dramatically increasing efficiency
Estimated fuel saving is 15% over current technology

Estimated new fleet – 2014 to 2035
A320 NEO, B737 MAX, B747 and B787 – 21,320 Aircraft¹

Potential 76 million mt CO₂ Savings per Year by 2035²

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



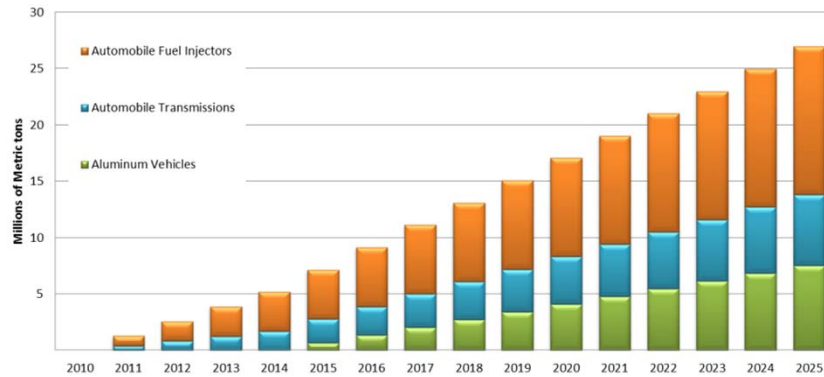
**10 YEAR
CUMULATIVE EFFECTS
ON CO2 EMISSIONS vs
BASELINE YEAR
37.6 million metric tons**

**520 thousand vehicles in
use**

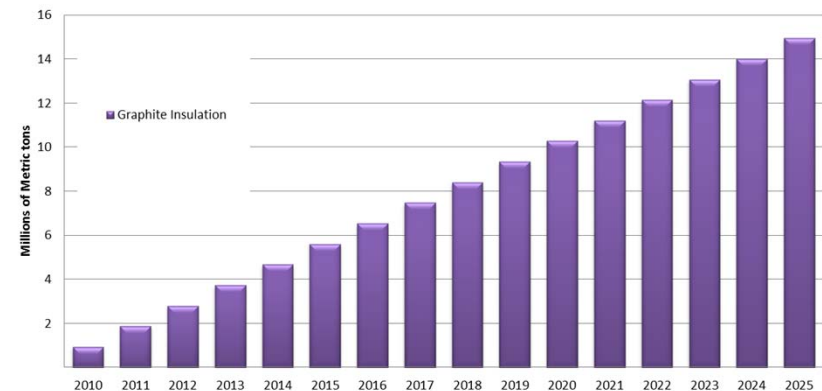
5.2 million vehicles in use

Enabling Technologies Summary

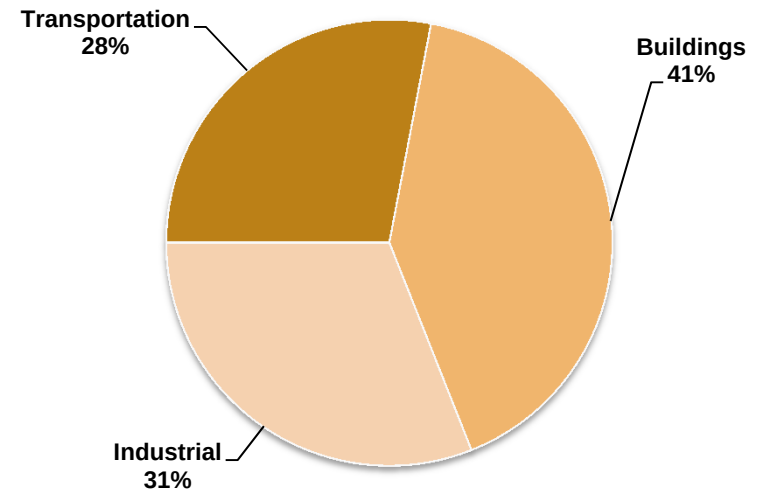
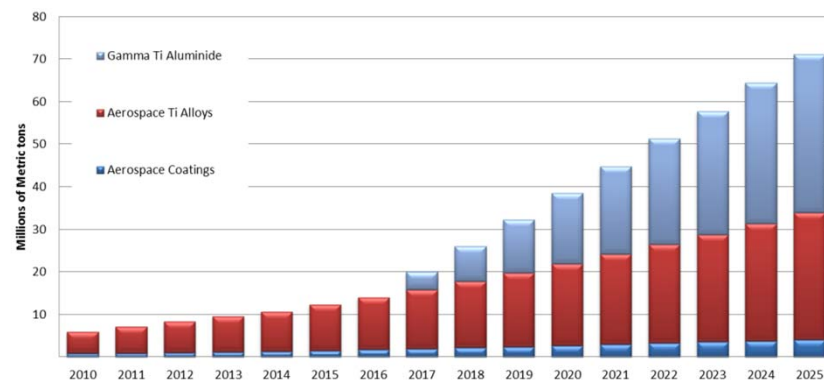
Automotive AMG Enabling Technologies Cumulative CO2e Reductions



Buildings AMG Enabling Technologies Cumulative CO2e Reductions

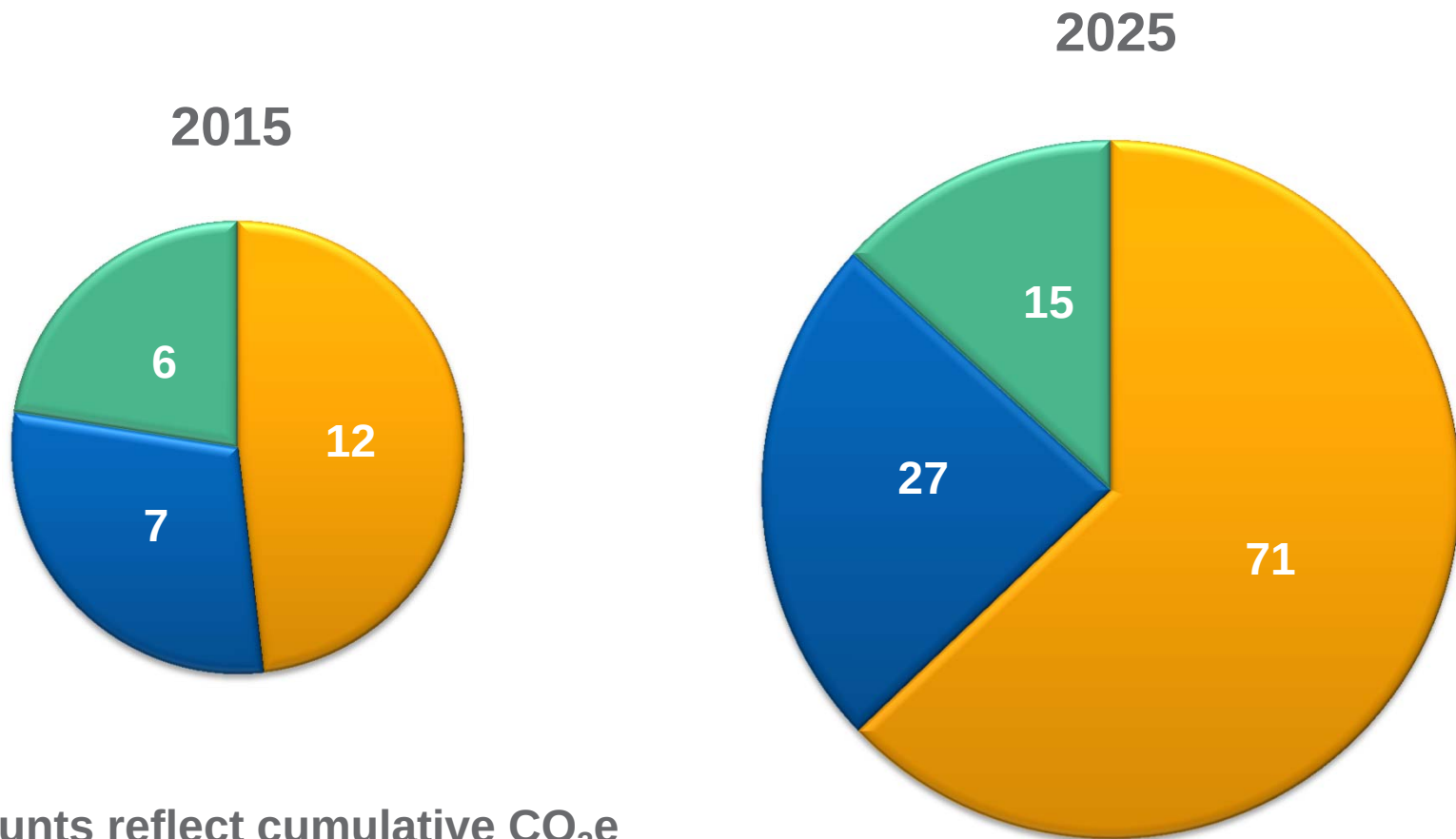


Aerospace AMG Enabling Technologies Cumulative CO2e Reductions



Enabling Technologies: 2015 vs. 2025

■ Aerospace ■ Automotive ■ Infrastructure



Amounts reflect cumulative CO₂e reductions in millions of metric tons

Ni

Al

Cr

Sb

C

Mo

Ta

Si

Ti

Nb

V

AMG