Sustainable & Environmentally Friendly Materials in Car Construction

Teaching Program created by ***Dr. Khrystyna BERLADIR****,*

Associate Professor, PhD.

Sumy State University, Ukraine

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Sumy State University

Personal Resume

Khrystyna BERLADIR,
Ph.D., Associate Professor

University — Sumy State University, Ukraine
https://int.sumdu.edu.ua/en/

Faculty — Faculty of Technical Systems and Energy Efficient Technologies
https://teset.sumdu.edu.ua/

Department — Department of Applied Materials Science and Technology of Structural Materials
https://pmitkm.teset.sumdu.edu.ua/

Contacts — Email: kr.berladir@pmtkm.sumdu.edu.ua

Sumy Region of Ukraine

- One of 24 Administrative-territorial units, North-East of Ukraine
- Population: 1.2 mln
- Area: 23.8 thousand km^2
- 30 km from the russian border

The domination of the industrial model in line with agricultural sector:

- Machine-building complex
- Pump and compressor equipment
- Chemical and oil industry
- IT sector

Delivering the Digital Future
Netcracker
An NEC Company

PORTA ONE

mind.k

AMCBRIDGE

Sumy State University in numbers

- **6 000** students (**12 000** before the full-scale war)
- **58** specialities on **24** branches of knowledge
- **300** international students from **30** countries
- **150+** Doctors of Sciences, Professors,
  550+ Doctors of Philosophy and Candidates of Sciences, Associate Professors
- **1000+** people study in **16** doctoral majors and **22** postgraduate majors

Sumy State Institutes and Faculties

- **Medical** Institute
- Institute of **Business, Economics and Management**
- Institute of **Law**
- Faculty of **Electronics and Information Technologies**
- Faculty of **Technical Systems and Energy Efficient Technologies**
- Faculty of **Foreign Philology and Social Communications**
- + 6 affiliated institutes and colleges
  located in other cities of Sumy Region

300 Partners

55 Countries

300+ Grants

Inspired by our mission to serve the community!

GLOBAL INTEGRATION

Membership in 25 organizations globally

Signatory of Magna Charta Universitatum

Ukrainian leader in the worldwide rankings

THE World University Ranking 801-1000
among the universities of the world and the **1st** place among the universities of Ukraine

THE Impact Rankings 201-300
in the top group of the world universities by success in achieving the United Nations' Sustainable Development Goals (**1st** place among higher education institutions of Ukraine)

THE World University Ranking 501-600
in the field of "Business and Economics" (**1st** place among higher education institutions (HEI) of Ukraine)

THE World University Ranking 601-800
in the field of "Engineering" (**1st** place among higher education institutions of Ukraine)

THE World University Ranking 601-800
in the field of "Physical Sciences" (**1st** place among higher education institutions of Ukraine)

THE World University Ranking 401-500
in the field of "Social Sciences" (**1st** place among higher education institutions (HEI) of Ukraine)

THE World University Ranking 601-800
in the field of "Medical and Health" (**1st** place among higher education institutions (HEI) of Ukraine)

THE Young University Rankings, 251-300
about "young" universities in the world, which are "growing rapidly", and are currently the only representative of Ukraine in this ranking

THE Interdisciplinary Science Rankings 251-300
in the top group of the world universities for the quality of interdisciplinary research (**1st** place among higher education institutions of Ukraine)

THE Online Learning Rankings
silver award in the world ranking of online learning

QS World University Rankings 1001-1200
in the top group of the leading world universities, on the **4th** position among the Ukrainian higher education institutions

QS World University Rankings: Europe
57 among the best universities in Eastern Europe, on the **8th** position among the Ukrainian higher education institutions

QS World University Rankings by Subject 551-700
in Economics & Econometrics (**2nd** place among Ukrainian universities)

QS Sustainability Rankings TOP-800
in the top group of the leading world universities, on the **2nd** position among the Ukrainian higher education institutions

QS Stars*****
by to the quantitative and qualitative teachers staff, students' satisfaction with the quality of education, the provision of educational and extracurricular activities, reputation among employers, the level of support for the career growth of graduates

University Ranking by Academic Performance
the **2nd** place among higher education institutions in Ukraine

Ranking Web of Universities (Webometrics)
the **2nd** place among higher education institutions in Ukraine

Webometrics Transparent Ranking
the 3rd place among higher education institutions of Ukraine according to citations of scientists in Google Scholar

Webometrics TOP-40
best institutional repositories of the world and the **1st** place among higher education institutions of Ukraine

UI GreenMetric TOP-330
universities of the world, on the **2nd** position among the Ukrainian higher education institutions this ranking

SCImago TOP-120
SCImago Institutions Rankings - in the top 120 universities of Eastern Europe and the **1st** place among higher education institutions in Ukraine

uniRank
the **7th** place among Ukrainian universities

Osvita.UA Rankings by Scopus
the **4th** place among Ukrainian universities

Top-200 Ukraine
the **5th** place among higher education institutions of Ukraine

SumDU International

- Sumy State University cooperates with over **370** partners from **66** countries.
- The UN, NATO, DAAD, American and British Council programs are covered as well. Annually, about **500 grants** are realized.
- SumDU implements over **85** long-term and short-term academic mobility programs (for Bachelor, Master and PhD students; researchers and lecturers).

Partner Universities

United Nations

NATO OTAN

Erasmus+

DAAD Deutscher Akademischer Austausch Dienst German Academic Exchange Service

AMERICAN COUNCILS FOR INTERNATIONAL EDUCATION

BRITISH COUNCIL

https://teset.sumdu.edu.ua/en/

Faculty of Technical Systems and Energy Efficient Technologies

8 Departments:

- Volodymyr Martsynkovskyy Computational Mechanics
- Manufacturing Engineering, Machines and Tools
- Chemical Engineering
- Ecology and Environmental Protection Technologies
- **Applied Material Science and Technology of Structural Materials**
- Applied Hydroaeromechanics
- Technical Thermophysics
- Theoretical and Applied Chemistry

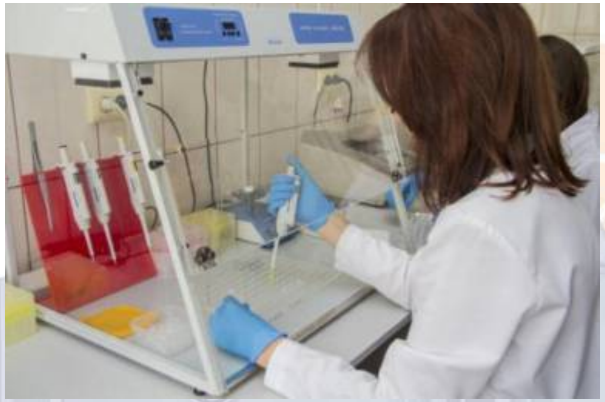
Cooperation and collaboration

Research Institutes and Centers

3 Research Institutes

26 Research and Training Centers

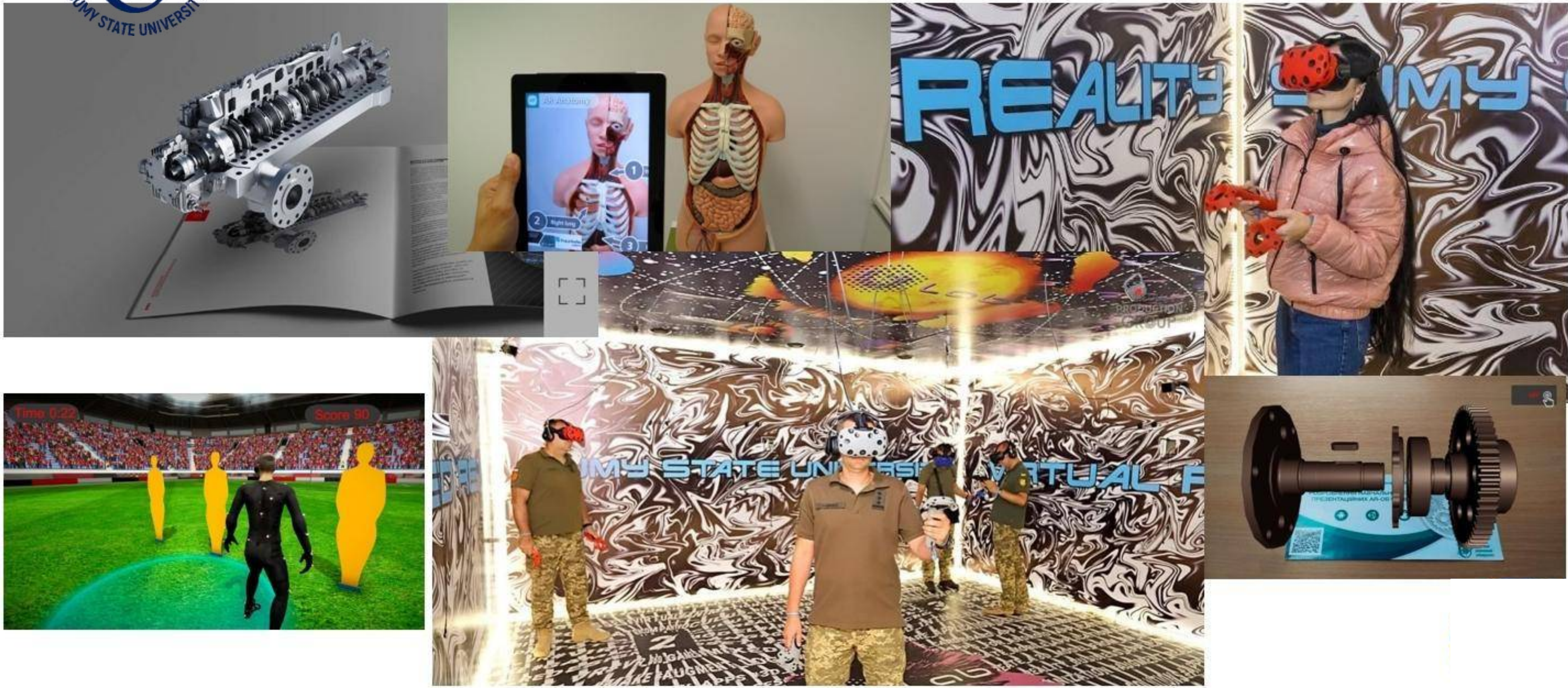
28 Research Laboratories



https://int.sumdu.edu.ua/en/research/research-institutes-centers.html

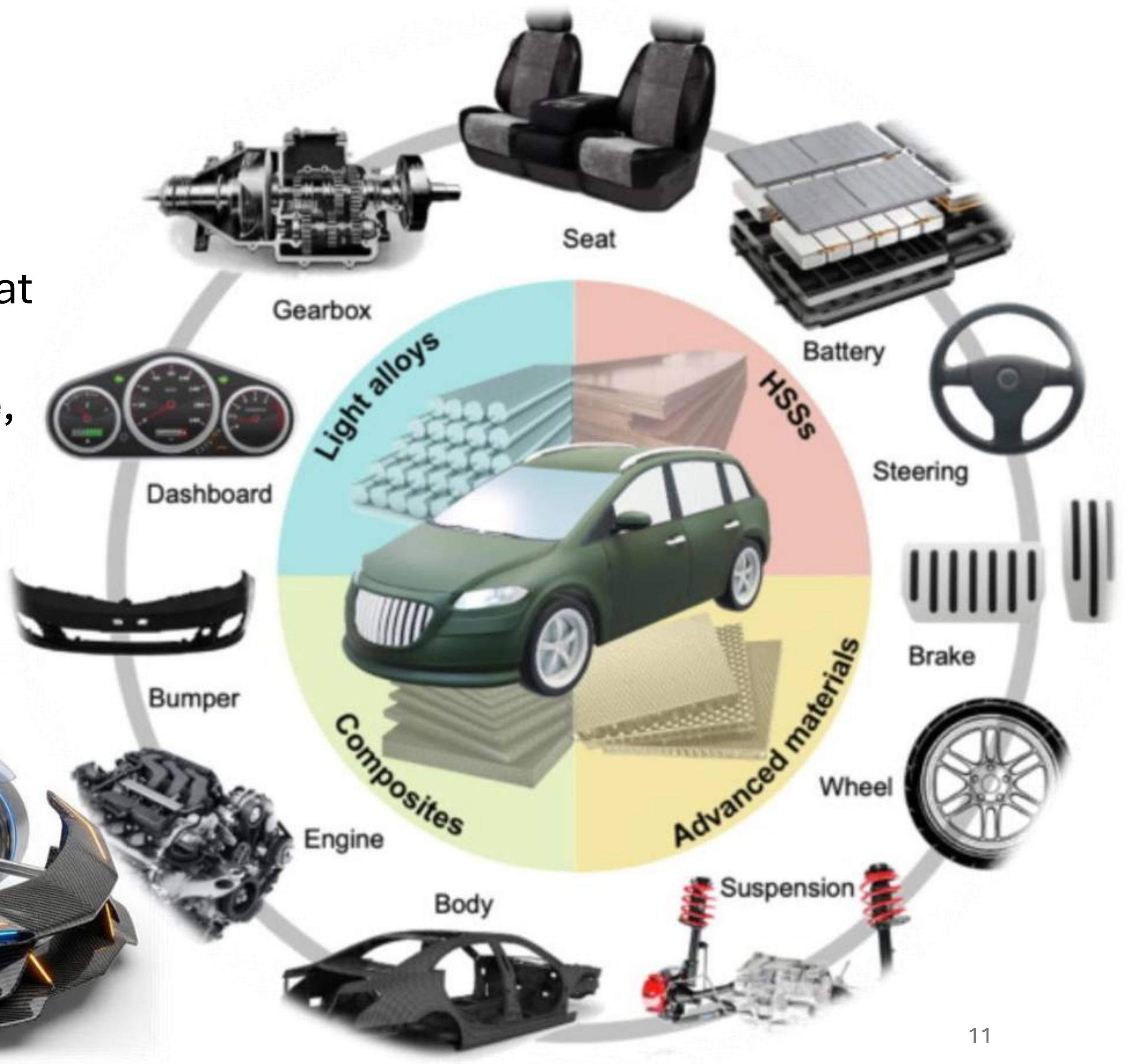
ULAB (VR/AR Laboratory)

https://ulab.sumdu.edu.ua



Modern Car

The **automotive industry** stands at the intersection of **technological innovation** and **material science**, driving progress and shaping the **future of transportation**.



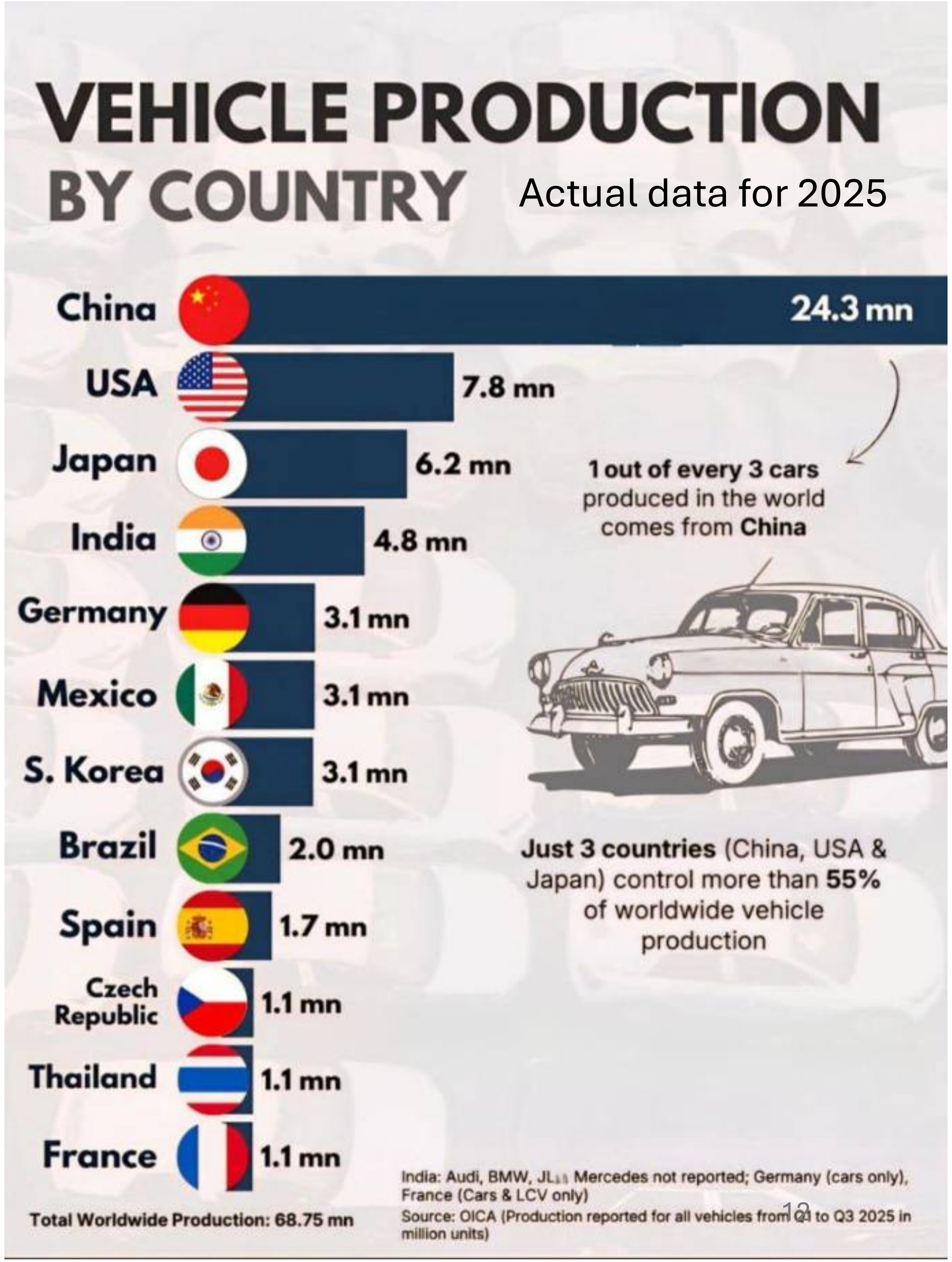
Global Production Shift

50M
Annual Production
Cars produced globally each year

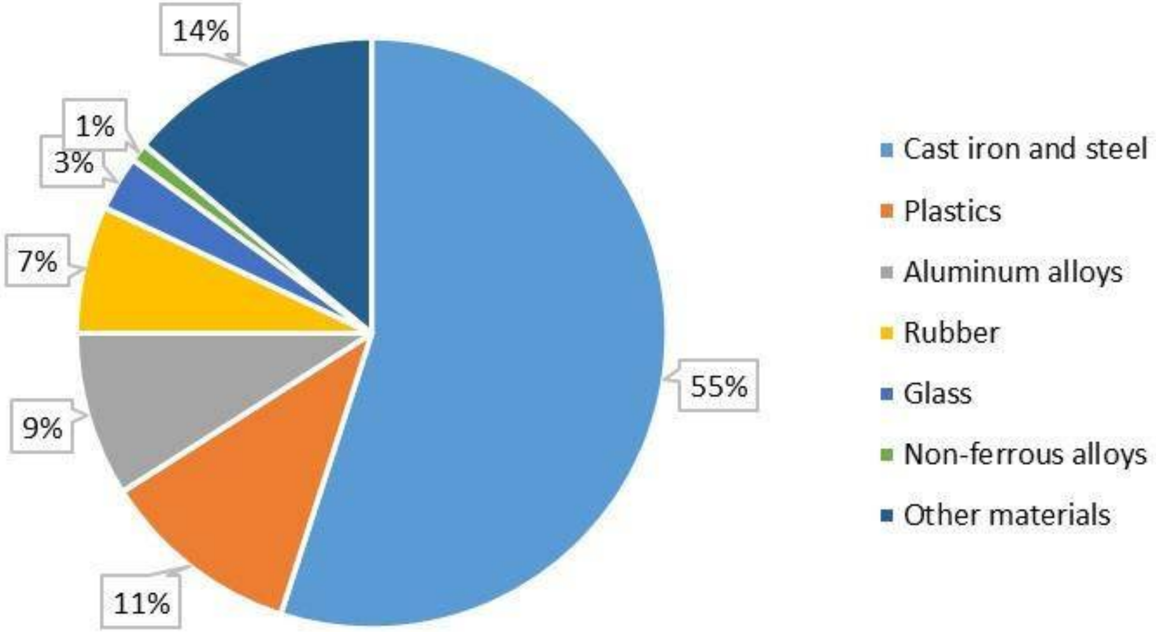
10
Leading Companies
Produce 80% of world's automobiles

60%
Foreign Production
Ford's cars made outside the U.S.

- BMW Group
- General Motors
- Mercedes-Benz Group
- Stellantis
- Toyota Motor
- Ford Motor
- Hyundai
- Renault
- Tesla
- Volkswagen Group



Material Composition Breakdown



Ferrous Metals

Cast iron and steel

Plastics

Lightweight components

Aluminum

High-strength alloys

⇄ Evolution Over Time

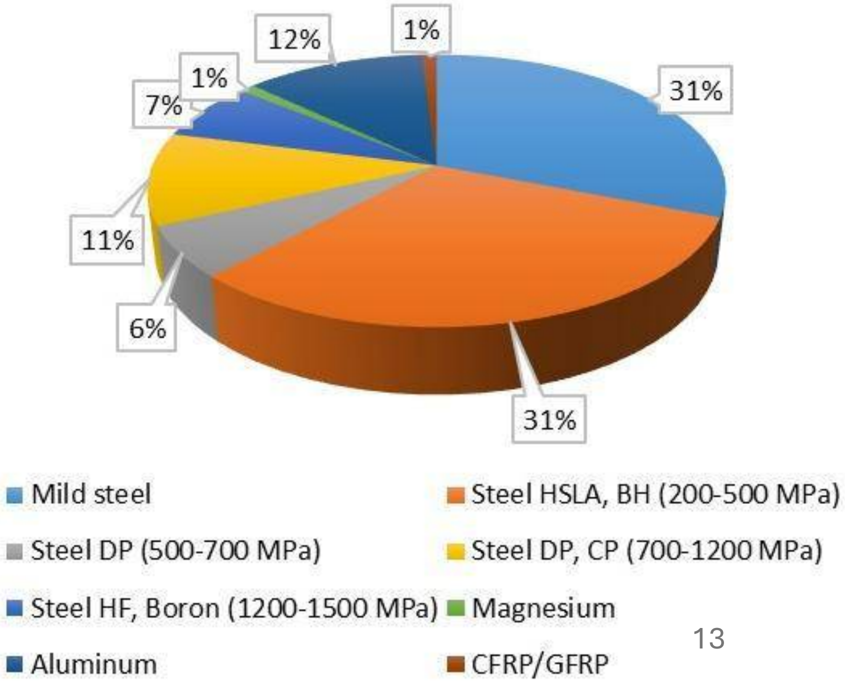
1980s: Steel 70%, Aluminum 4%, Plastics 8%

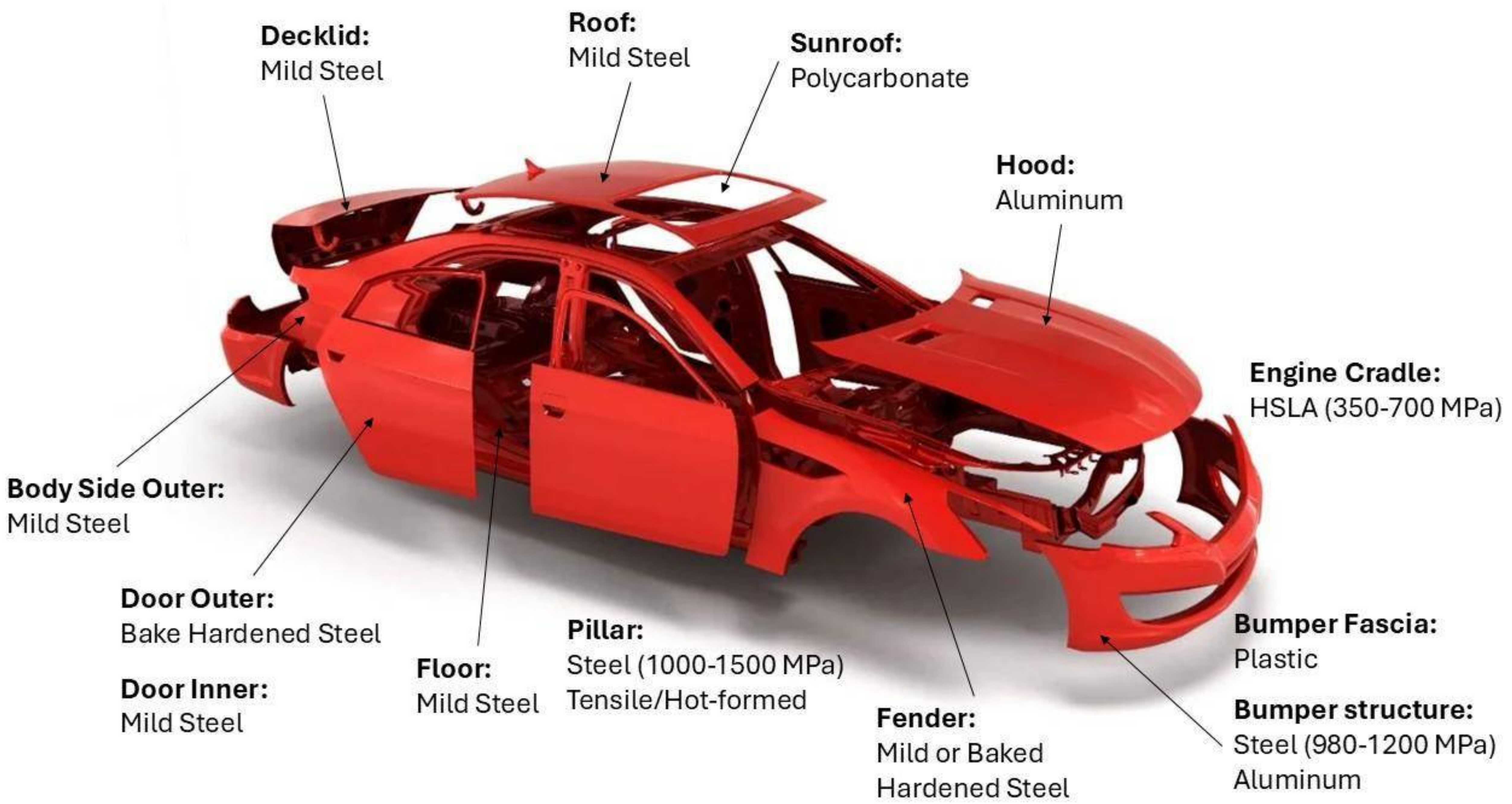
2000s: Steel 62%, Aluminum 8%, Plastics 12%

2020s: Steel 55%, Aluminum 12%, Plastics 15%

2040 (projected): Steel 45%, Aluminum 18%, Composites 20%

more details

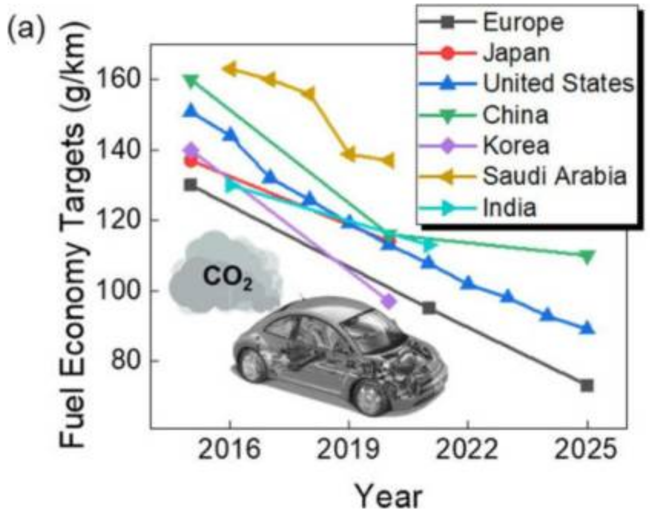



Decklid:
Mild Steel
Roof:
Mild Steel
Sunroof:
Polycarbonate
Hood:
Aluminum
Engine Cradle:
HSLA (350-700 MPa)
Body Side Outer:
Mild Steel
Door Outer:
Bake Hardened Steel
Door Inner:
Mild Steel
Floor:
Mild Steel
Pillar:
Steel (1000-1500 MPa)
Tensile/Hot-formed
Fender:
Mild or Baked
Hardened Steel
Bumper Fascia:
Plastic
Bumper structure:
Steel (980-1200 MPa)
Aluminum

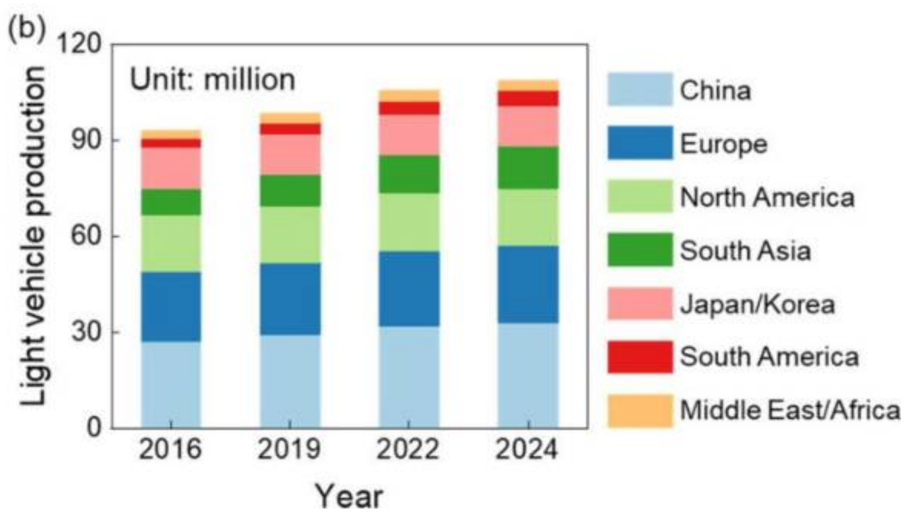
Main Challenges

10% Weight Reduction = 6–8% Improvement in Fuel Economy

This is the fundamental driver for the global transition to advanced materials.

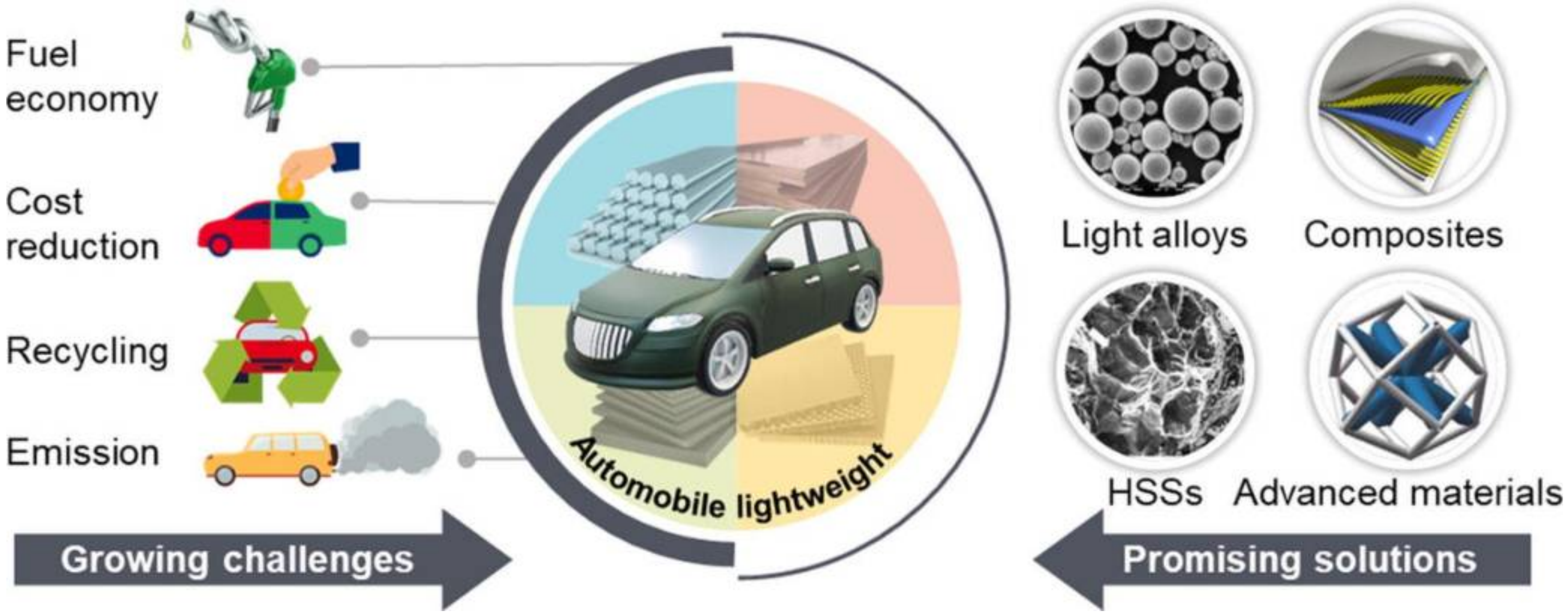


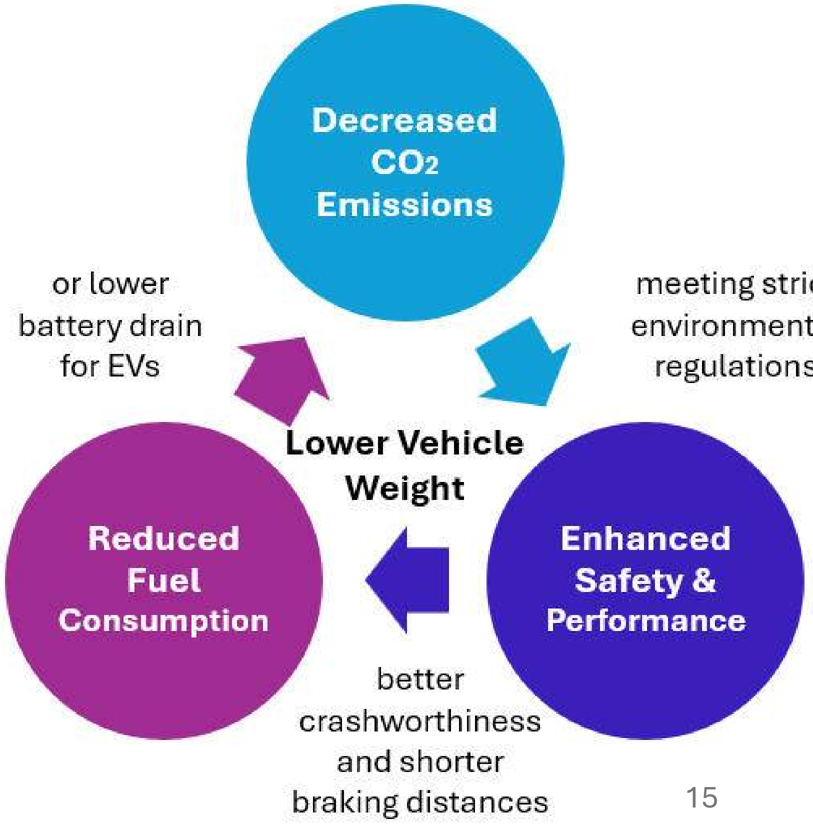
Fuel economy targets in different countries (passenger vehicles)



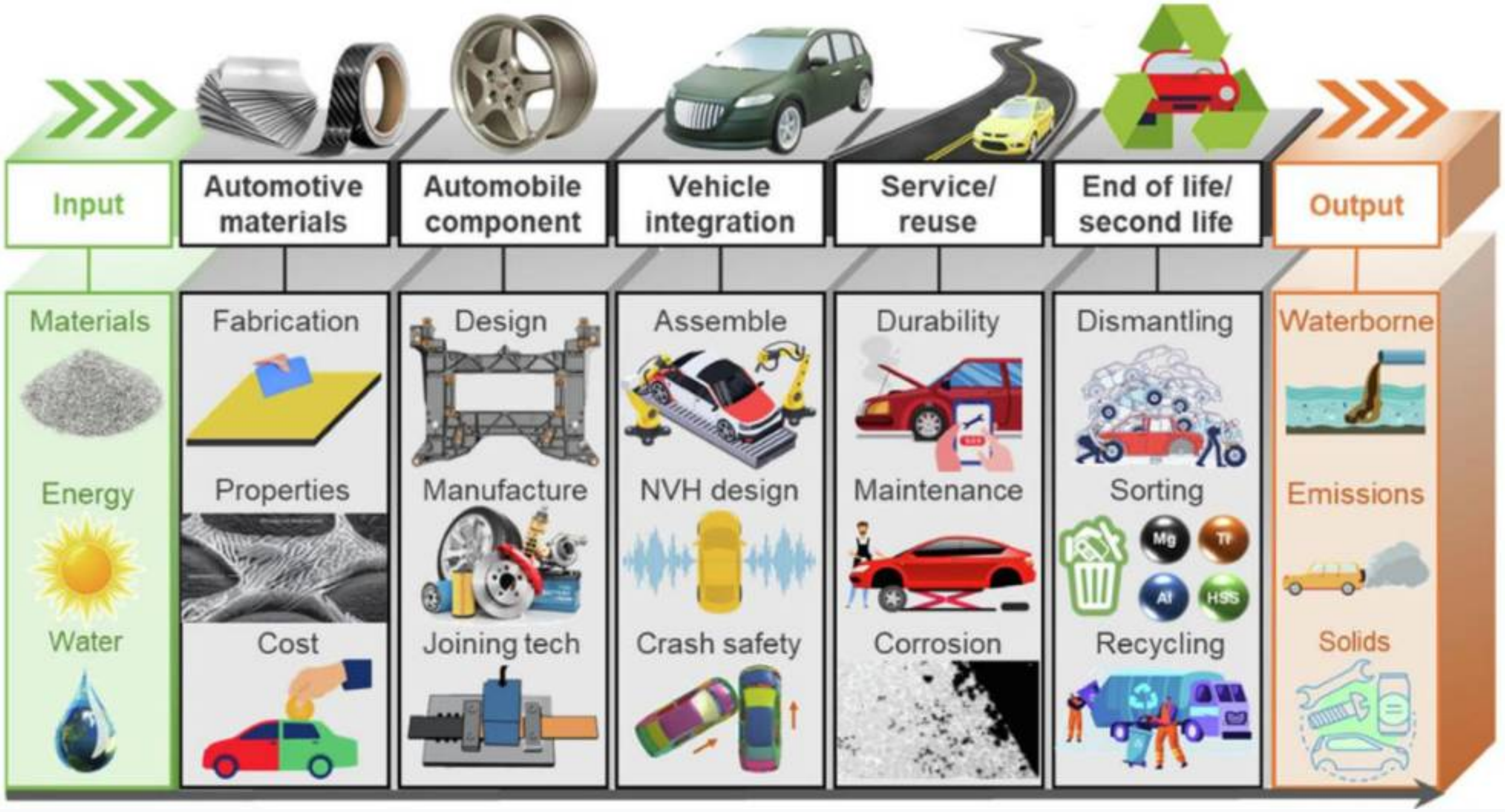
Light vehicle production by the major market in million units

Challenges / Solutions





Entire Life Cycle of Automotive Materials



Life Cycle Thinking: Each stage has environmental impacts that must be considered in material selection. The goal is to minimize total life cycle impact while meeting performance and cost requirements.

Environmental Impact

Raw Material Extraction
Energy intensive, mining impacts

Manufacturing
Process emissions, waste generation

Use Phase
Fuel consumption, emissions

End-of-Life
Recycling potential, landfill diversion

Key Considerations

- ✓ Embodied energy of materials
- ✓ Recyclability and recovery rates
- ✓ Transportation impacts
- ✓ Second-life applications

Material Selection Criteria Framework

"The Right Material in the Right Place"

This fundamental principle guides modern automotive design engineers in optimizing material selection for each vehicle component based on specific performance requirements, manufacturing constraints, and cost targets.

Selection Criteria Categories

Mechanical Properties

Strength, ductility, toughness, fatigue resistance, hardness

Physical Properties

Density, thermal conductivity, expansion coefficient

Environmental Resistance

Corrosion resistance, chemical stability, UV resistance

Economic Factors

Material cost, processing cost, availability

Design Constraints

Supply Chain

Material availability, supplier reliability, lead times

Infrastructure

Manufacturing capabilities, equipment compatibility

Environmental

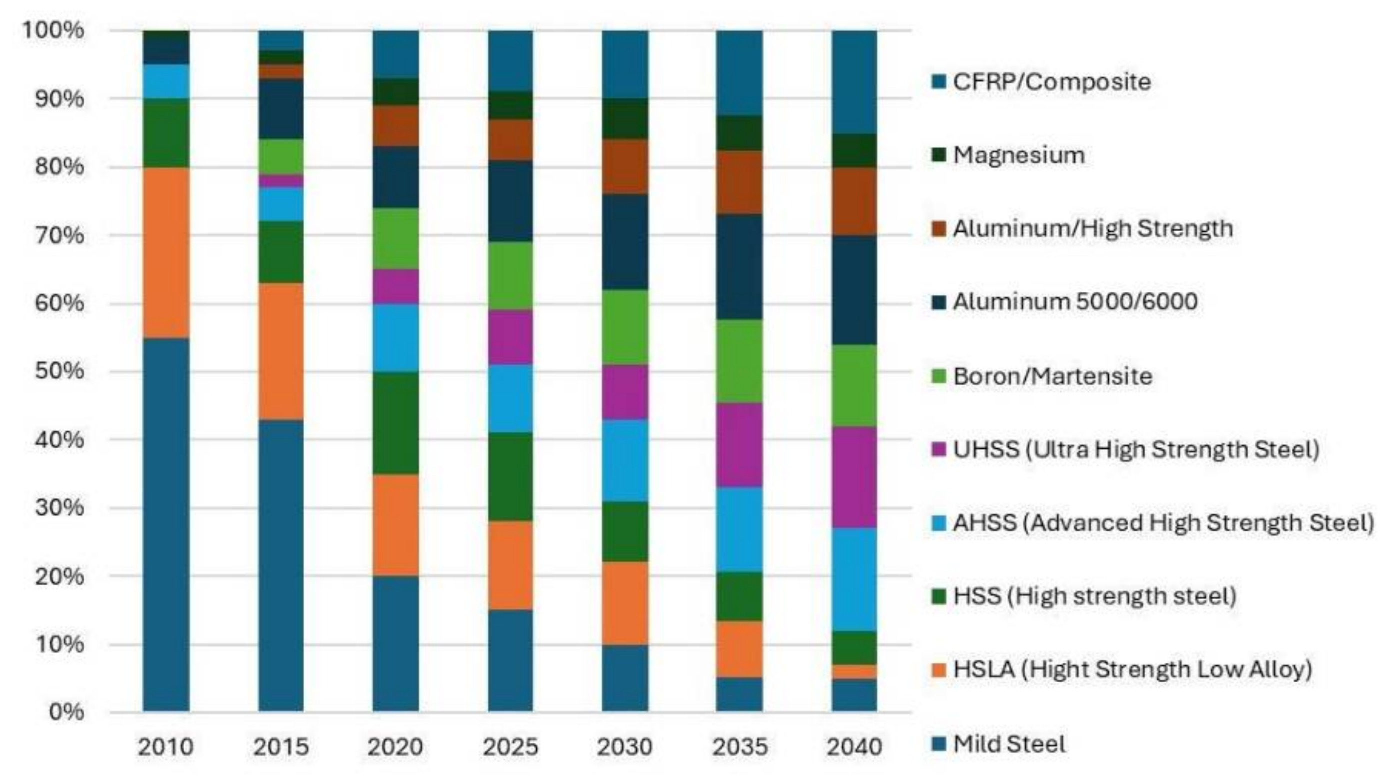
Regulations, recyclability, carbon footprint

Decision Process

1. Define performance requirements
2. Identify candidate materials
3. Evaluate against criteria
4. Conduct cost-benefit analysis
5. Validate through testing
6. Optimize for production

Future Trends and Projections to 2040

Projected Material Usage Evolution (2020-2040)



Key Projections

Steel Decline

From 65% (2020) to 45% (2040)

Aluminum Growth

From 10% to 18% share

Composites Expansion

From 8% to 20% share

Magnesium Increase

From 0.5% to 3% share

Emerging Materials

- Carbon fiber reinforced polymers (CFRP)
- Natural fiber composites
- Aluminum-lithium alloys
- Smart materials (SMAs)
- Bio-based polymers

The Future of Mixed Materials

Material Substitution Matrix: Traditional vs. Advanced Materials

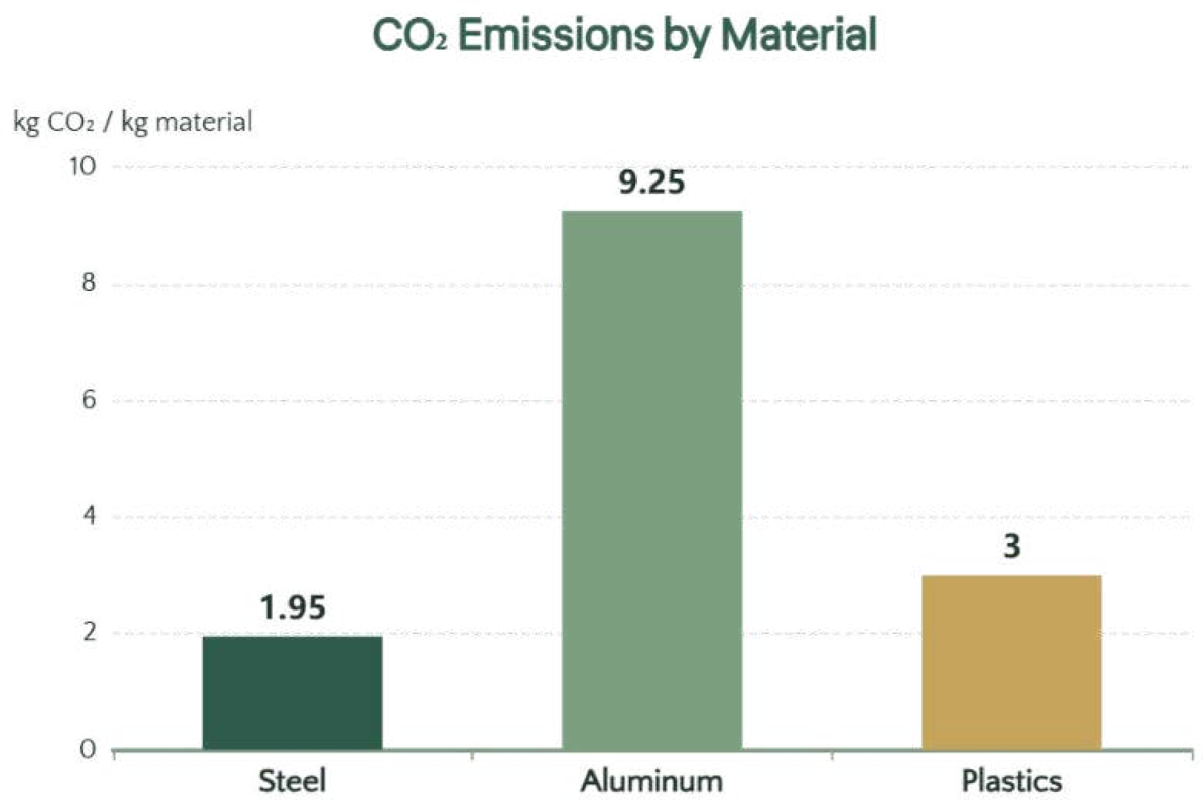
Traditional Material	Advanced Replacement	Weight Reduction	Relative Cost
Low Carbon Steel	HSS (High-Strength Steel)	10-25%	1.0×
Steel	Polymer composites (GFRP)	25-35%	1.0-1.5×
Steel, Cast Iron	Aluminum	40-60%	1.3-2.0×
Foundry Steel	Titanium	40-55%	1.5-10×
Steel or Cast Iron	Magnesium	60-75%	1.5-2.5×
Steel	Polymer composites (CFRP)	50-60%	2-10×
Steel or Cast Iron	Al-matrix composites	50-65%	1.5-3×

75%
Maximum Weight Reduction (Mg vs. Steel)

Cost-Benefit
Trade-off analysis essential for each application

Multi-Material
Optimal mix for performance and cost

The Carbon Footprint of Traditional Materials



Steel Production

1.8-2.1 kg CO_2/kg

High emissions from iron ore processing

Aluminum Smelting Smelting

8.5-10 kg CO_2/kg

Extremely energy-intensive process

Plastic Manufacturing

2.5-3.5 kg CO_2/kg

Petrochemical-based production

Critical Insight: The automotive industry accounts for significant global CO_2 emissions through material production alone.

The Shift to Sustainability

Regulatory Pressure

Stringent emission targets and ELV Directive compliance requirements driving material innovation.

Consumer Demand

Growing awareness and preference for eco-friendly vehicles among environmentally conscious buyers.

Innovation Drive

R&D advancements enabling high-performance sustainable materials at competitive costs.

Bio-Based Plastics: Sustainable Solutions

Classification of Bio-Based Plastics

Group 1: Bio-based, Non-Biodegradable

Durable plastics from renewable sources:

- Mass commodity plastics: bio-PE, bio-PET
- Technical polymers: PTT, TPC-ET, bio-PA

Group 2: Bio-based & Biodegradable

Can be used in durable applications:

- **PLA** (Polylactic acid)
- **PHA** (Polyhydroxyalkanoates)
- **PBS** (Polybutylene succinates)

Key Benefits

- Reduced fossil fuel dependence
- Lower carbon footprint
- Comparable performance
- Design flexibility

Figure 10: PLA from corn to biodegradable products

Polylactic Acid (PLA)

Production Process

Derived from renewable resources: **corn starch, tapioca, sugarcane** . Only **1.6 kg of biomass** required to make 1 kg of PLA.

Mechanical Properties vs PP

Tensile Strength 59 MPa	Elongation 3%
Flexural Strength 85 MPa	Izod Impact 33.4 J/m

Automotive Applications

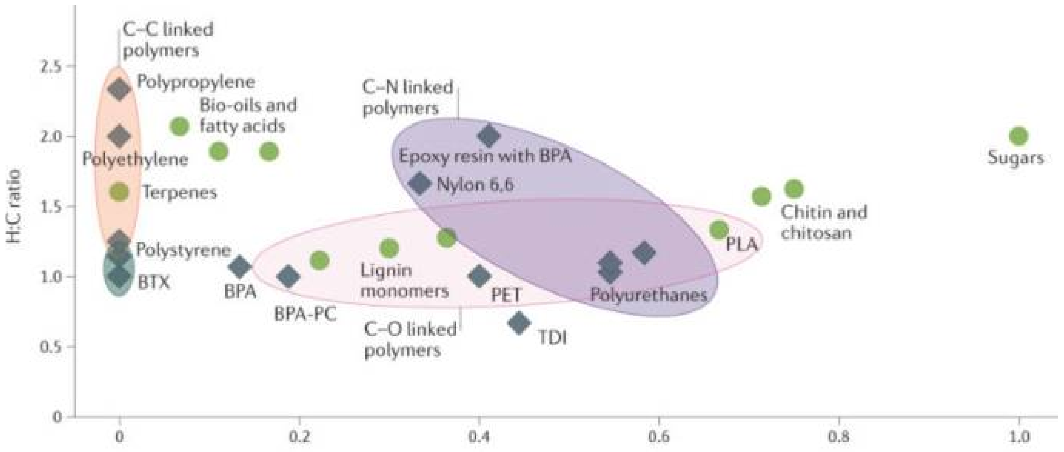
- **Mazda 5:** Console, seat covers
- **Lexus ES300:** Package shelves
- **Ford U model:** Roof, floor carpets

Recycling Methods

- Mechanical recycling
- Chemical recycling (depolymerization, hydrolysis)

Note: PLA biodegrades in **3-6 months** under industrial composting conditions (60°C, humidity, microbes). In normal conditions, it can take **100-1000 years** .

PLA & Biodegradable Polymers



Polylactic Acid (PLA)

- Derived from corn starch or sugarcane
- 100% bio-based & compostable
- Ideal for 3D printing applications
- Used by Volvo for foamed interior parts

Other Biodegradable Polymers

PHA — Polyhydroxyalkanoates
Bacterial-produced, marine biodegradable

PBS — Polybutylene Succinate
Bio-succinic acid based, good fiber affinity

PBAT — Polybutylene Adipate Terephthalate
Flexible, used in blends for durability

Degradation Process

Heat & Moisture → Microorganisms → CO_2 + H_2O + Biomass

Bio-Polyamides & Polyesters

Castor Oil-Based Based

EcoPaXX® (DSM)

70% bio-based polyamide for Mercedes engine covers

Ultramid® Balance (BASF)

Partially castor oil-based PA for Mazda rear bumpers

Rilsan® (Arkema)

100% bio-based polyamide 11 for fuel lines

Benefits: Low moisture absorption, high melting point, chemical resistance

Sugarcane-Based

Bio-PET (Toyota)

Used in headliners, sunvisors, floormats

Sorona® (DuPont)

37% plant-based polymer for interior parts

Bio-PE

Polyethylene from sugarcane ethanol

Benefits: Higher stiffness, better thermal shock resistance, easier processing

Industry Recognition

Fiat & DuPont won SPE Automotive Innovation Award for castor oil-based fuel lines

60%

Bio-based interior fabrics in Toyota Prius

Plastic Recycling in Automotive Industry

Recycling Methods & Technologies

1 Mechanical Recycling

Most established method. Shredding and reprocessing **without** significantly changing chemical structure.

Suitable for: Thermoplastics | **Limitation:** Complex composites

2 Chemical Recycling

Changes polymer structure into chemical building blocks (monomers). Includes **gasification, pyrolysis, hydrocracking, depolymerization**.

Advantage: High-quality output | **Process:** Dissolution, purification

3 Energy Recovery

Incineration of plastic waste while using energy for electricity, steam, or process heat. Last option with less environmental pollution.

Figure 11: Automotive circular economy model

Industry Examples

Škoda

Scala model: 14 kg of parts from recycled plastics. **ENYAQ iV:** Wool + recycled polyester seat covers

Ford

Seat fabric from **-22 plastic bottles** per Focus. Closed-loop recycling of manufacturing scraps.

Volvo

Target: 25% recycled plastic by 2025. Dashboard from recycled fibers, seats from PET bottles, carpet from fishing nets.

Renault

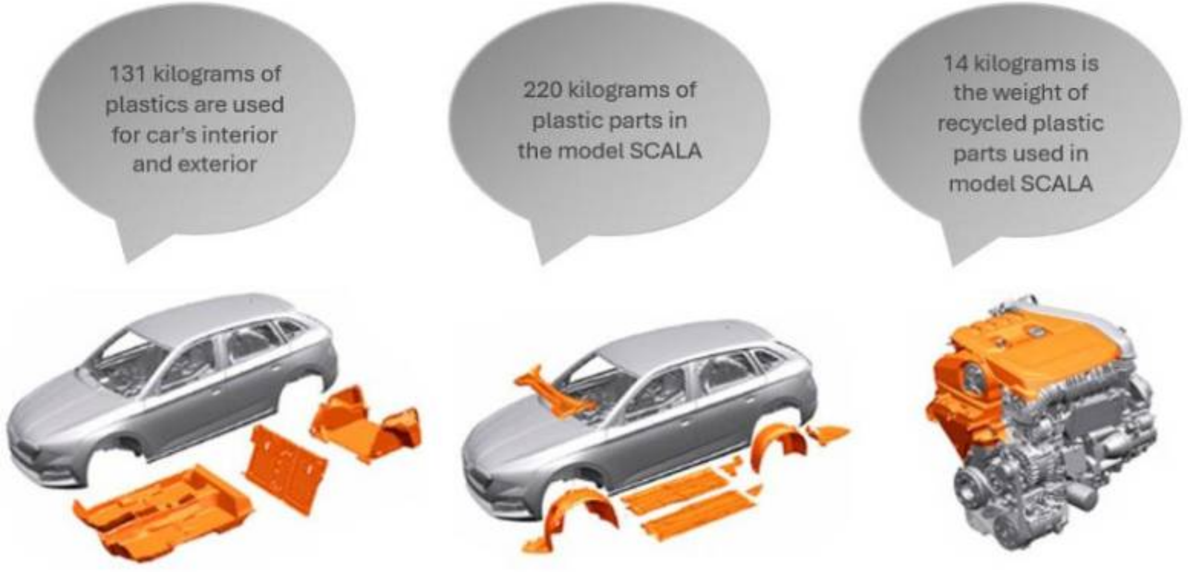
Closed-loop economy: recovering PP from bumpers and wheel arch coverings for new parts.

Current Status

Recycled plastics in automotive:	-25%
ELV plastic derivatives (2015):	17%
Forecast for 2030:	-20%

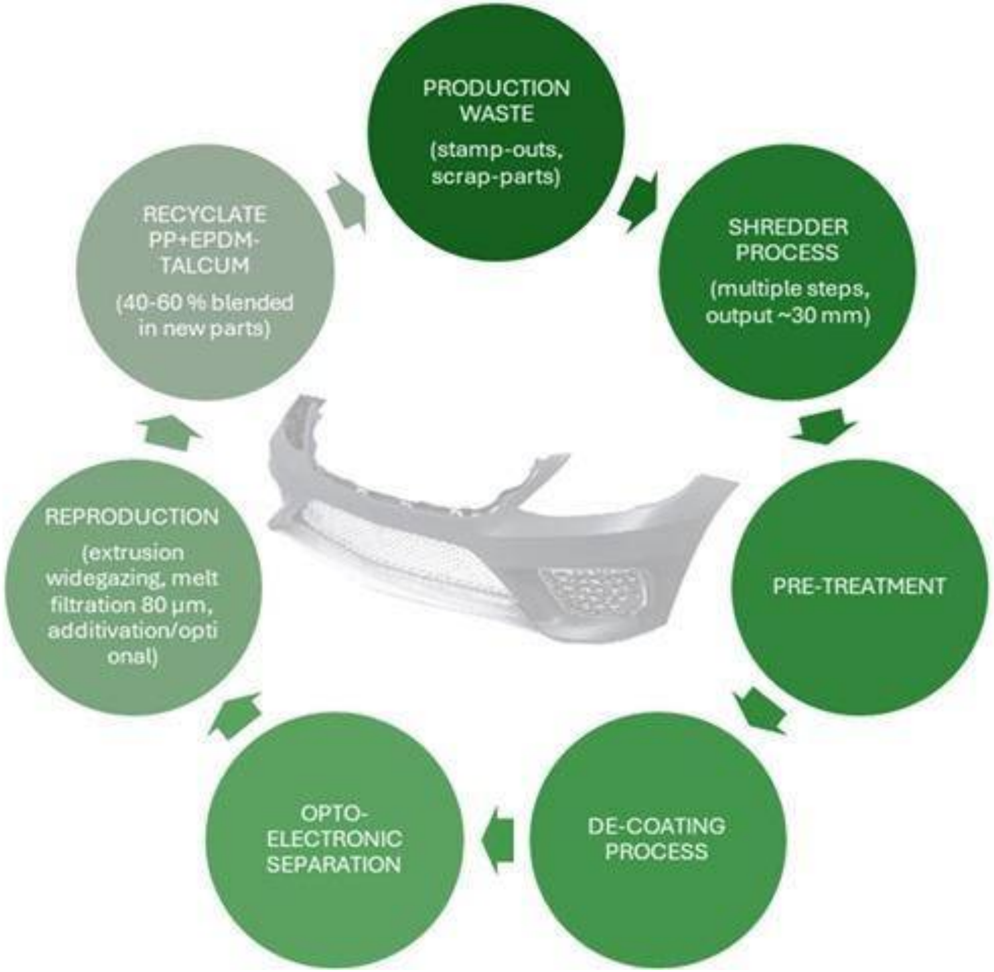
Challenge: Increase recycled materials while maintaining quality and safety standards.

Application of recycled plastics in Škoda Scala model (orange in pictures).

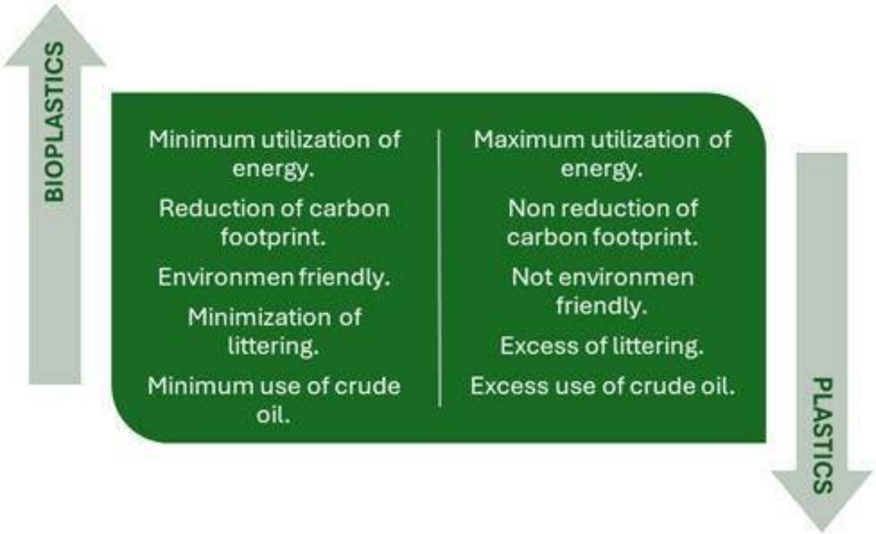


Closed-loop-recycling

(value chain: bumper → to bumper).



Bioplastics vs. petroleum-based plastics



Recycled Plastics Revolution

Closed-Loop Recycling

1. Collection of production scrap
2. Sorting & shredding
3. Melting & reprocessing
4. New automotive parts

Key Recycled Polymers

rPP
Recycled Polypropylene — Bumpers, interior panels

rABS
Recycled ABS — Dashboards, trim components

rPA
Recycled Polyamide — Carpet backing, under-hood

rPC
Recycled Polycarbonate — Headlights, mirrors

Applications

- Bumpers & grilles
- Dashboard panels
- Engine covers
- Seat frames
- Floor mats
- Trunk liners

Recycled Metals: The Circular Economy

Aluminum

Infinitely Recyclable

95% **Energy Savings**
vs. primary production

95% **CO_2 Reduction**
Lower carbon emissions

Steel

Most Recycled Material

74% **Recycling Rate**
Highest of all materials

∞ **Endless Recycling**
Without quality loss

Closed-Loop System

1. **Production Scrap**
   Automotive manufacturing waste collected
2. **Return to Facility**
   Scrap transported to recycling plants
3. **Melt & Reform**
   Reintroduced into supply chain

Recycled Aluminum Advantage

Infinite Recyclability

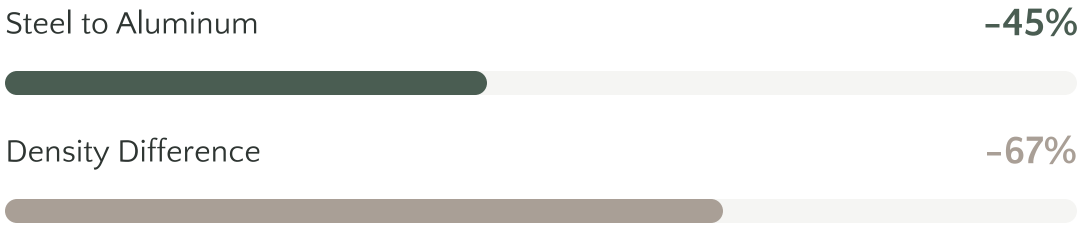
95% Energy Savings
vs. primary aluminum production

∞ Endless Recycling
Without quality degradation

Automotive Applications

- Body panels
- Doors & hoods
- EV battery enclosures
- Engine components
- Wheels
- Crash structures

Weight Reduction



Introduction to Biocomposites

Definition

Composite materials made from **natural-based reinforcement** and resins. At least one
At least one component must be a renewable resource.

Three Categories

1. **Synthetic Matrix + Natural Reinforcement**
   Most common type
2. **Natural Matrix + Synthetic Reinforcement**
   Bio-based resins
3. **Natural Matrix + Natural Reinforcement**
   "Green Biocomposites"

Common Abbreviations

NFRC NFRP WPC

Critical Processing Parameter

≤ 200°C

Maximum Processing Temperature

Above this temperature, cellulose fibers decompose

Polymer Matrix Types

Thermosets

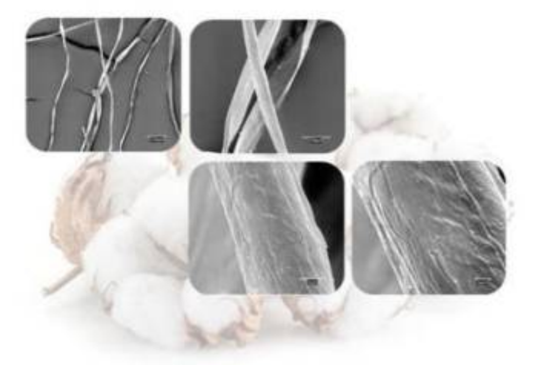
Epoxy, Polyester, Phenolic

Stronger bonds, non-recyclable

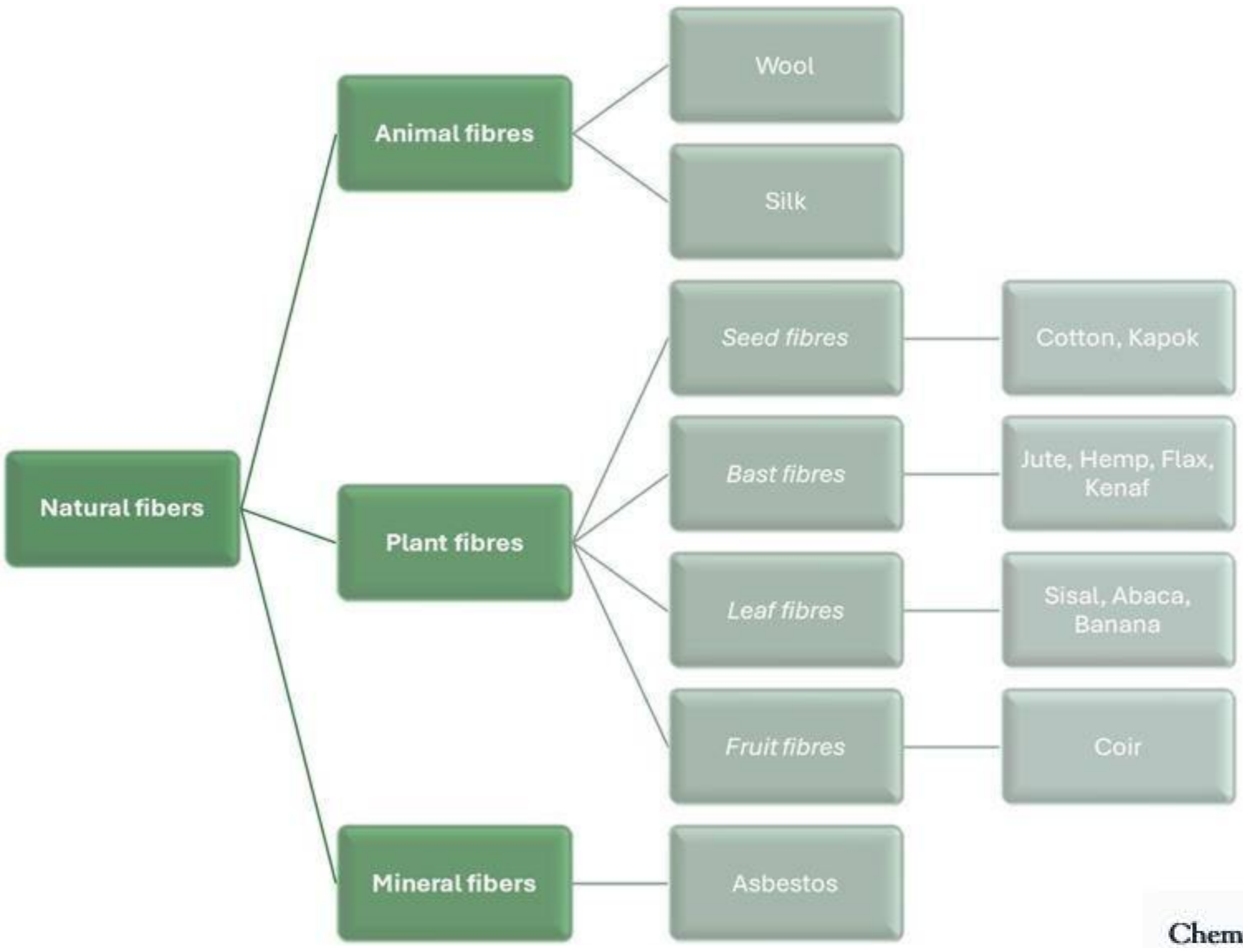
Thermoplastics

PE, PP, PS, PVC

Recyclable, easier processing



Natural Fibers: Classification and Structure



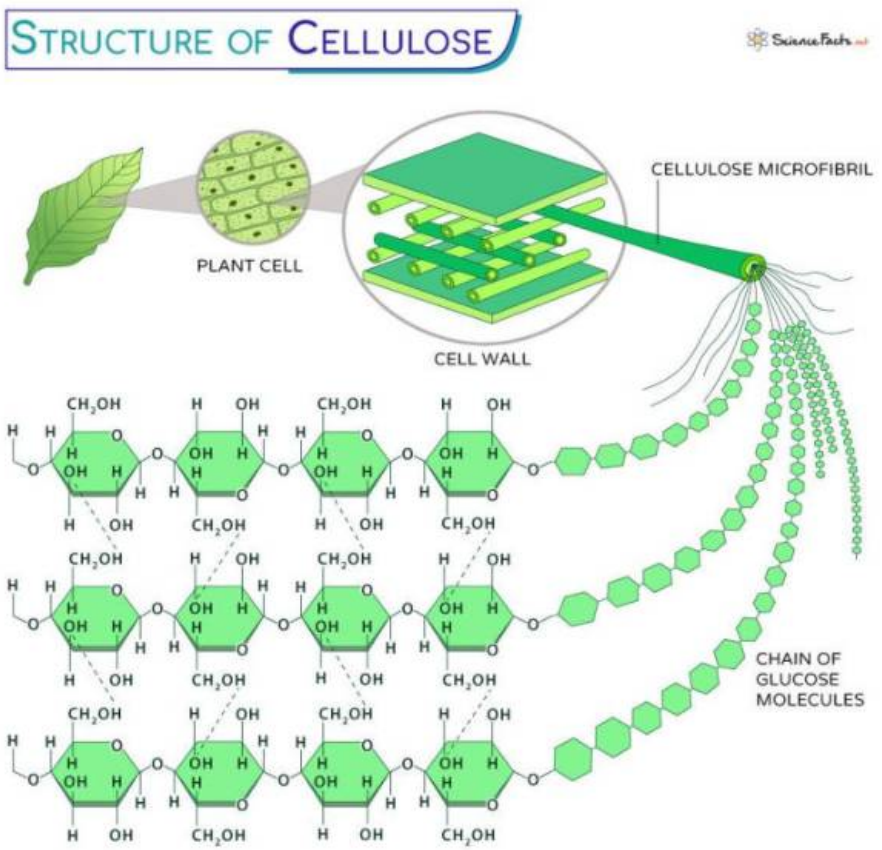
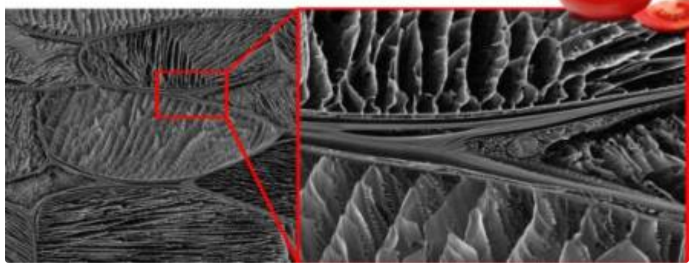


Figure 2: Natural Fiber Microstructure



Chemical Composition

Cellulose	Major structural element
Hemicellulose	Supporting polymer
Lignin	Binding agent
Pectin, Waxes	Minor components

Properties: Natural vs. Glass Fibers

Table 1: Comparison of Fiber Properties

Fiber Type	Density[g/cm³]	Tensile Strength[MPa]	Elongation[%]	Tensile Modulus[GPa]
Flax	1.4	500-900	1.2-1.6	**60-80**
Hemp	1.48	300-800	1.6	**30-70**
Jute	1.46	200-800	1.8	**20-55**
Cotton	1.51	300-600	3-10	**6-12**
E-Glass	**2.55**	**2400**	**3**	**73**

Advantages

- **~50% lower density** than glass fibers
- **Similar tensile modulus** to glass fibers
- **Renewable resource** - environmentally friendly
- **Biodegradable** at end of life
- **Cost-effective** compared to synthetic fibers

Disadvantages

- **Lower tensile strength** (vs. glass fibers)
- **High moisture absorption**: 8-12.6%
- **UV degradation** susceptibility
- **Poor fire resistance**
- **Incompatibility** with hydrophobic matrices

Fiber Modification Techniques

Physical Techniques

Plasma Treatment

Improves surface properties through chemical implantation, etching, polymerization, free radical formation

Environmentally friendly & cost-effective

Corona Discharge

Enhances surface energy and functional properties of natural fibers

Modification Goals

- Reduce Moisture
- Improve Adhesion
- Enhance Durability
- Fire Resistance

Chemical Techniques

Alkali Treatment (Mercerization)

Uses NaOH (caustic soda) to clean and modify fiber surface

Effect: Enhanced fiber-polymer adhesion

Acetylation

Grafts acetyl groups onto cellulose structure using catalyst

Effect: Reduced moisture absorption susceptibility

Binder Addition

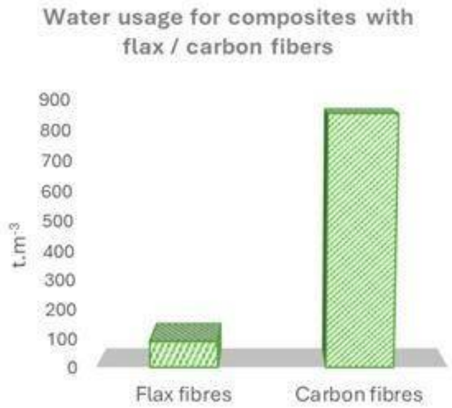
Isocyanates, Silane coupling agents

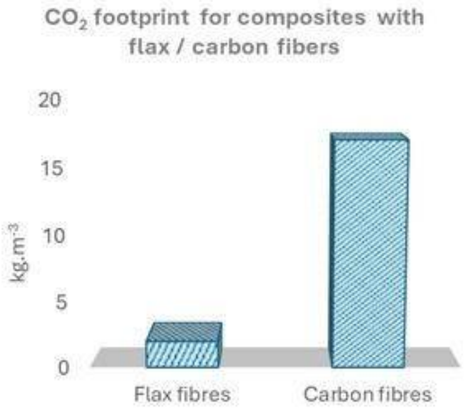
Effect: Increased strength and stiffness

Figure 3: Hemp Fiber Reinforcement

Natural Fiber Composites

Flax Fiber: Nature's Carbon Fiber





Exceptional Properties

- **80%** — **Carbon Reduction** compared to synthetic fibers
- **500–1500** — **MPa Tensile Strength** — comparable to glass fiber
- **80** — **GPa Young's Modulus** — excellent stiffness

Automotive Applications

- Door Panels
- Dashboards
- Seat Backs
- Interior Trim
- BMW M Racing
- Mercedes C-Class

Natural Fiber Composites

Hemp & Jute: Strong & Sustainable

Hemp Fiber

Rapidly growing in popularity due to its sustainability and durability. Can be woven into fabrics or used in composites.

- → High tensile strength & durability
- → Pest & mildew resistant
- → Used in headliners & dashboards

Jute Fiber

One of the most economical natural fibers. High tensile strength and low extensibility make it ideal for reinforcing polymers.

- → Cost-effective solution
- → Excellent for door panels
- → Compatible with thermoset resins

Key Benefits

1. **Lightweight**
   30-60% energy reduction in production
2. **Biodegradable**
   70-90% biodegradability at end of life
3. **Sound Absorption**
   Improves acoustic quality in cabins

Natural Fiber Composites

Kenaf & Other Natural Fibers

Kenaf

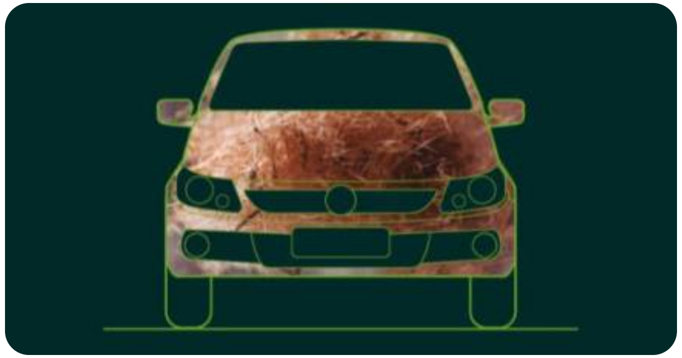
Rapid growth and high strength-to-weight ratio. Used extensively in BMW 7 Series door panels and Toyota vehicles.

Growth Rate: 4-5 months to maturity

Sisal

Derived from agave plants, sisal fibers offer excellent durability and are increasingly used in composite applications.

Application: Seat backs, interior panels



Pineapple Leaf

Piñafelt from pineapple leaves creates high-performance composites with excellent mechanical properties.

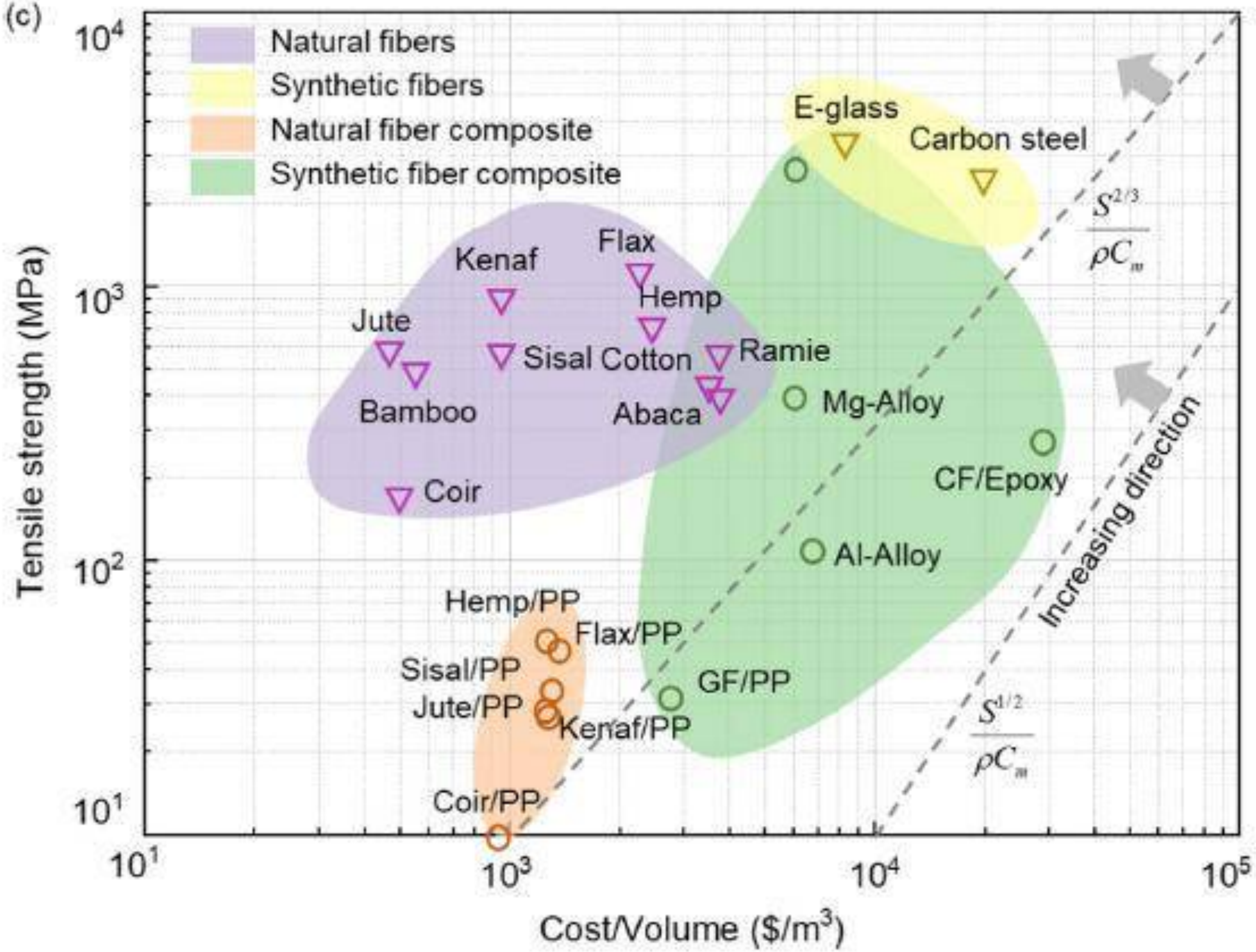
Origin: Agricultural waste product

Industry Adoption

Mercedes, BMW, Toyota, Audi, Ford all use natural fiber composites

50%

Carbon Reduction



(c)
Natural fibers
Synthetic fibers
Natural fiber composite
Synthetic fiber composite
E-glass
Carbon steel
Flax
Kenaf
Hemp
Jute
Sisal
Cotton
Ramie
Bamboo
Abaca
Mg-Alloy
Coir
CF/Epoxy
Al-Alloy
Hemp/PP
Flax/PP
Sisal/PP
Jute/PP
Kenaf/PP
GF/PP
Coir/PP
Increasing direction
$\frac{S^{2/3}}{\rho C_m}$
$\frac{S^{1/2}}{\rho C_m}$
Tensile strength (MPa)
Cost/Volume ($/m³)

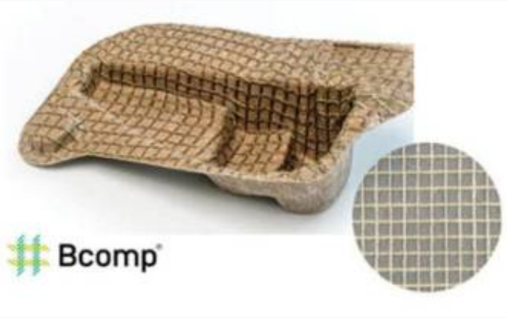
Leading Companies and Products

Bcomp Ltd. (Switzerland)

"Biocomposites of the Year 2019" Nominee

powerRibsÂ
Hemp-based reinforcement for high-performance composites

AmpliTexÂ
Flax fiber reinforcement



Applications:
- Volvo XC60, Porsche
- McLaren F1 racing seats

85% lower CO_2 emissions

Faurecia (France)

Part of Forvia Group - Market leader since 1980s

NAFILeanÂ
45% hemp fibers in PP matrix

NAFILean-PF2 555 Properties:
- Density: 0.98 g/cm³
- Tensile Modulus: 2650 MPa
- MFR: 11.6 g/10 min

Table 2: Automotive Applications by Manufacturer

Company	Model	Material	Application
BMW	7-series	Natural fiber mats + acrylic	Door panels
Mercedes	S-class	Flax + hemp + sisal/PU	Inner door panel
Audi	A2	PU + sisal/flax blend	Door trim panels
Ford	Mustang GT RTD	Epoxy + flax fabric	Body panels, spoilers
Toyota	Kijang Minibus	Kenaf/phenolic resin	Door trim
Renault	5 E-Tech	Hemp/recycled PP+PET	Interior applications

BIO-COMPOSITES

Bio-Composites in Action

Polestar 5 & Bcomp: Leading the natural fiber revolution

Weight Reduction

40%

Lighter than conventional plastic composites

Virgin Plastic Reduction

50%

Less virgin plastic required

Polestar 5 Features

- Flax fiber seatbacks
- Interior trunk lid
- Console side panels

Bcomp Technologies

- **ampliTex™** – Reinforcement fabrics
- **powerRibs™** – Stiffness enhancement

Wood-Plastic Composites (WPC)

Composition

1. **Polymer Matrix**
   PE, PP, PVC, PS or thermosets
   thermosets
2. **Wood Flour**
   Maple, oak, pine (aspect ratio l/d: 1-5)
   1-5)
3. **Additives**
   Coupling agents, lubricants, flame retardants

Manufacturing Process

Step 1: Size Reduction
Hammer mill or chipper processing

Step 2: Size Classification
Screening through mesh sieves (e.g., 20 mesh = 850 μm)

Step 3: Mixing & Processing
Temperature < 200°C to prevent wood decomposition

Figure 6: WPC Products

Processing Methods

Extrusion Primary method	**Injection Molding** Complex shapes
Compression Large panels	**Thermoforming** Custom parts

Processing Techniques for NFRP Composites

Thermosetting Polymers

Hand Lay-up — Manual
Simple, cost-effective for prototypes

RTM — Resin Transfer
Resin injected into fiber preform

Compression Molding — High Volume
Heat and pressure application

Filament Winding — Cylindrical
For tanks, pipes, pressure vessels

Pultrusion — Continuous
Constant cross-section profiles

VARTM — Vacuum
Vacuum-assisted resin transfer

Thermoplastic Polymers

Injection Molding — Short Fibers
High-volume production of complex parts

Extrusion — Long Fibers
Continuous profiles and sheets

Compression Molding — Long Fibers
Large, flat components

Thermoforming — Continuous
Heated sheet formed over mold

Pultrusion — Continuous
Constant cross-section profiles

Thermostamping — Continuous
High-speed forming process

Practical Concept Application

FUTURE MATERIALS

Cellulose & Beyond

Next-generation sustainable automotive materials

Nano Cellulose Cellulose

Japan's revolutionary vehicle material from wood pulp

Weight 1/5
of steel weight

Strength 5×
stronger than steel

Agave Fibers

From tequila production waste to automotive components

Jose Cuervo Partnership
200-300 tons harvested daily

- Wiring harnesses
- HVAC units
- Storage bins

Bamboo & Algae Algae

Fast-growing renewable resources for interior applications

Bamboo Benefits

- Matures in 2-5 years
- Compostable material
- Tensile strength of steel

Algae Research
Bio-plastics & foam alternatives

Innovation Focus: These materials represent the next frontier in sustainable automotive design, combining performance with environmental responsibility.

Bamboo: 10x Growth Advantage

Why Bamboo?

10x — **Faster Growth**
vs. traditional timber

3yr — **Harvest Time**
Ready for production

CO_2 — **Carbon Absorption**
Fixes large amounts of CO_2

Lexus Applications

- Steering wheels
- Interior door panels
- Seat trim accents
- Dashboard elements

Processing Techniques

1. **Dry Distillation:** Stabilizes the material
2. **Steam Treatment:** Enhances durability
3. **Lamination:** Parallel fiber bonding

Bamboo Composites in Action

Bamboo Fiber Composites

Bamboo fiber composites are replacing glass fiber in automotive applications, offering significant environmental benefits while maintaining performance.

30% Carbon Reduction
vs. petroleum-based materials

17% Weight Reduction
in door panels & armrests

Real-World Applications

- **Ford Mondeo:** Bamboo-origin trunk felt
- **FAW J6P Truck:** Roof panels with bamboo fiber
- **Yanfeng:** Door panels with 30% lower emissions

Product Range

- Headliners
- Door panels
- Trunk liners
- Seat backs
- Carpet systems
- Interior trim

RECYCLED PLASTICS

Giving Waste New Life

Transforming ocean waste into automotive components

BMW i3 Innovation

30% recycled plastic in front bumper trim, 85% recyclable plastic overall

Recycled Fishing Nets
Nets

Polestar Econyl® carpets from discarded fishing nets

30% recycled maritime plastic in BMW i3 storage compartments

PET Bottle Recycling
Recycling

Polestar 4: 89% recycled PET upholstery

100% recycled yarn from PET bottles

29.1% CAGR for recycled plastics through 2035

SUSTAINABLE INTERIORS

Natural Materials Inside

Luxury meets sustainability in modern vehicle cabins

BMW i3 Interior

Interior

- **Eucalyptus Wood**
  Open-pore, certified sustainable
- **Olive Leaf Leather**
  Naturally tanned, chemical-free
- **Recycled PET**
  Seat covers & textiles
- **Wool & Kenaf**
  Natural fiber blend

Hyundai Ioniq

Ioniq

25%
Wood cellulose plastic

20%
Palm seed paint extract

Tencel® Seats
Eucalyptus cellulose

Polestar Innovation

Innovation

- Reconstructed birch wood
- 89% recycled PET

ALTERNATIVE LEATHERS

Piñatex & Alternative Leathers

Revolutionary materials from agricultural waste

Weight Advantage

75%

Lighter than traditional leather

Cost Efficiency

2/3

The price of conventional leather

Automotive Applications

- Floor mats (current)
- Seat upholstery (emerging)
- Interior trim panels

Piñatex by Ananas Anam

Made from pineapple leaf fibers — 25 million tons harvested annually, previously burned or left to rot

Pineapple & Plant-Based Leathers

Piñatex® — Pineapple Leather

- Made from pineapple leaf fibers
- Agricultural waste product
- Customizable textures & colors
- Used in seat covers & trims

Other Plant-Based Alternatives

Apple Leather
Made from apple peel waste

Cactus Leather
Desserto® from cactus plants

Grape Leather
Wine industry byproduct

Cork Leather
Sustainable cork oak bark

Sustainability Metrics

Water Usage Reduction 95%

Carbon Footprint Reduction 80%

No Toxic Chemicals 100%

Mushroom Leather: Fine MyceliumǺ

What is Fine MyceliumǺ ?

Fine Mycelium™ is a proprietary biotechnology platform that engineers mycelium—the renewable root structure of mushrooms—to craft customizable leather alternatives.

- Grown using wheat bran, water & sawdust
- Production time: days vs. years for leather
- Made-to-order & made-to-specification

Cadillac SOLLEI Concept

1. **First Automotive Application**
   Charging mats & door map pockets
2. **GM Ventures Investment**
   Part of $125M funding round
3. **Commercial Scale Production**
   Millions of sq ft annually at full capacity

From Ocean to Automobile

The Problem

- 14M tons of plastic enter oceans yearly
- Fishing nets endanger marine life
- Plastics take 100s of years to degrade

Industry Leaders

BMW
ECONYL® floor mats from fishing nets

Ford
Bronco Sport cable leads from ocean plastic

Kia
EV3 trunk liner with 40% ocean plastic

The Solution

1. **Collect**
   Fishing nets & ropes from ports
2. **Process**
   Clean, shred & transform into pellets
3. **Manufacture**
   Create durable automotive parts

The Ocean Cleanup Partnership

Kia × The Ocean Cleanup

- Partnership since 2022
- First car accessory from Great Pacific Garbage Patch
- 40% recycled ocean plastic in EV3 trunk liner
- 20% increase target by 2030

Environmental Impact

CO_2 Reduction	25%
Marine Life Protection	100%
Material Performance	Equal

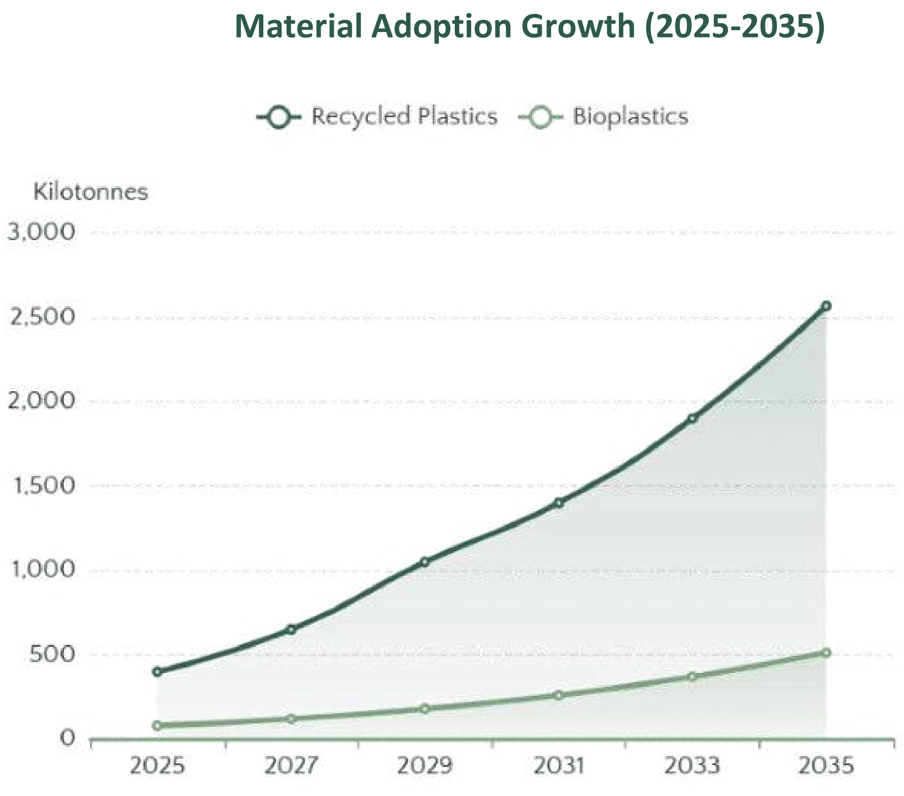
BMW Innovations

- Recycled fishing nets & ropes
- Injection molding process
- Visible & non-visible trim parts
- 40% secondary materials by 2030

FUTURE PROJECTIONS

2030 and Beyond

Market trends and regulatory landscape



Recycled Plastics

29.1%

CAGR through 2035

Bioplastics

25.1%

CAGR through 2035

EU Regulation

25%

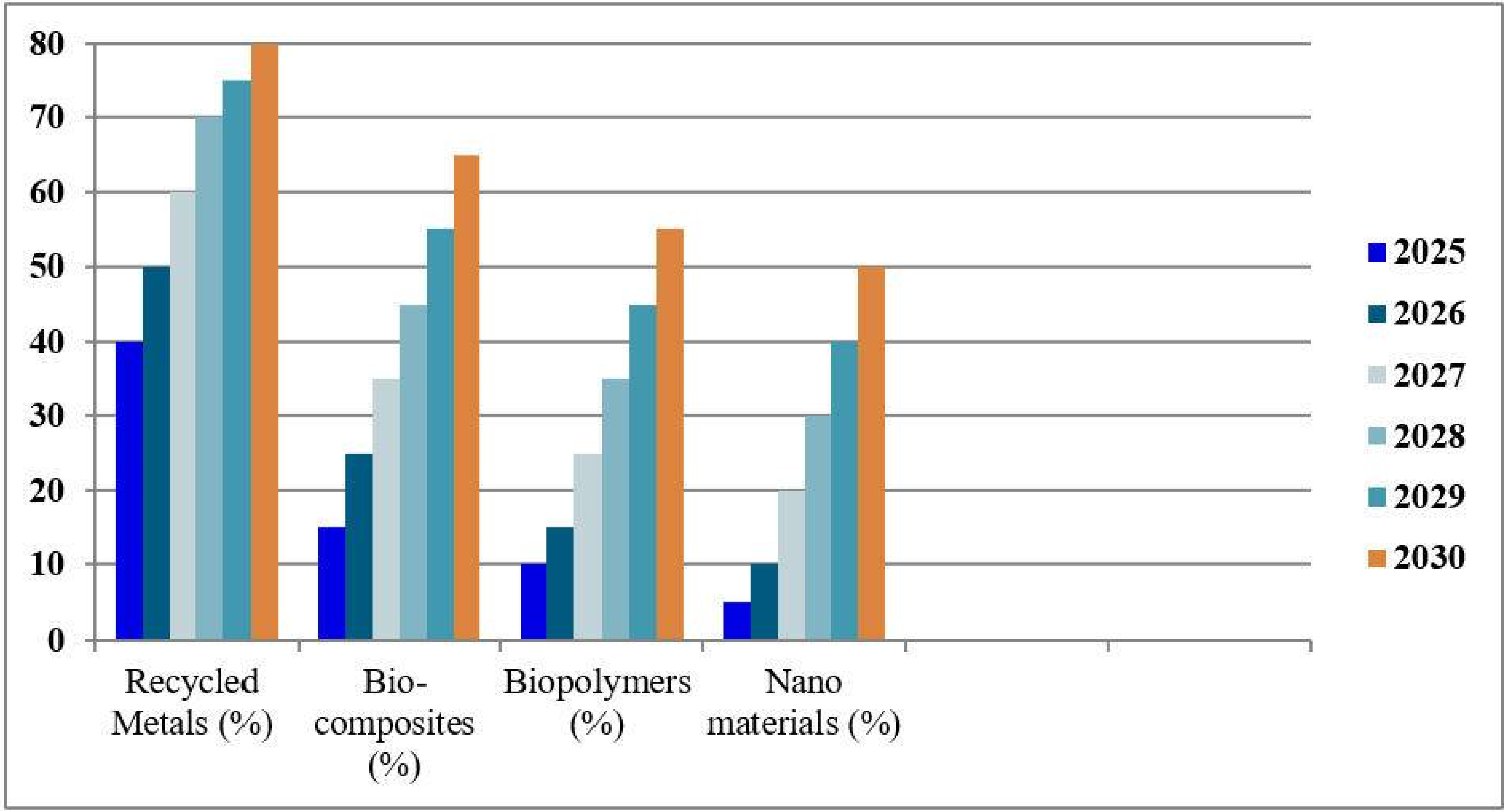
Recycled content mandate

3D Printing
Bio-based feedstocks

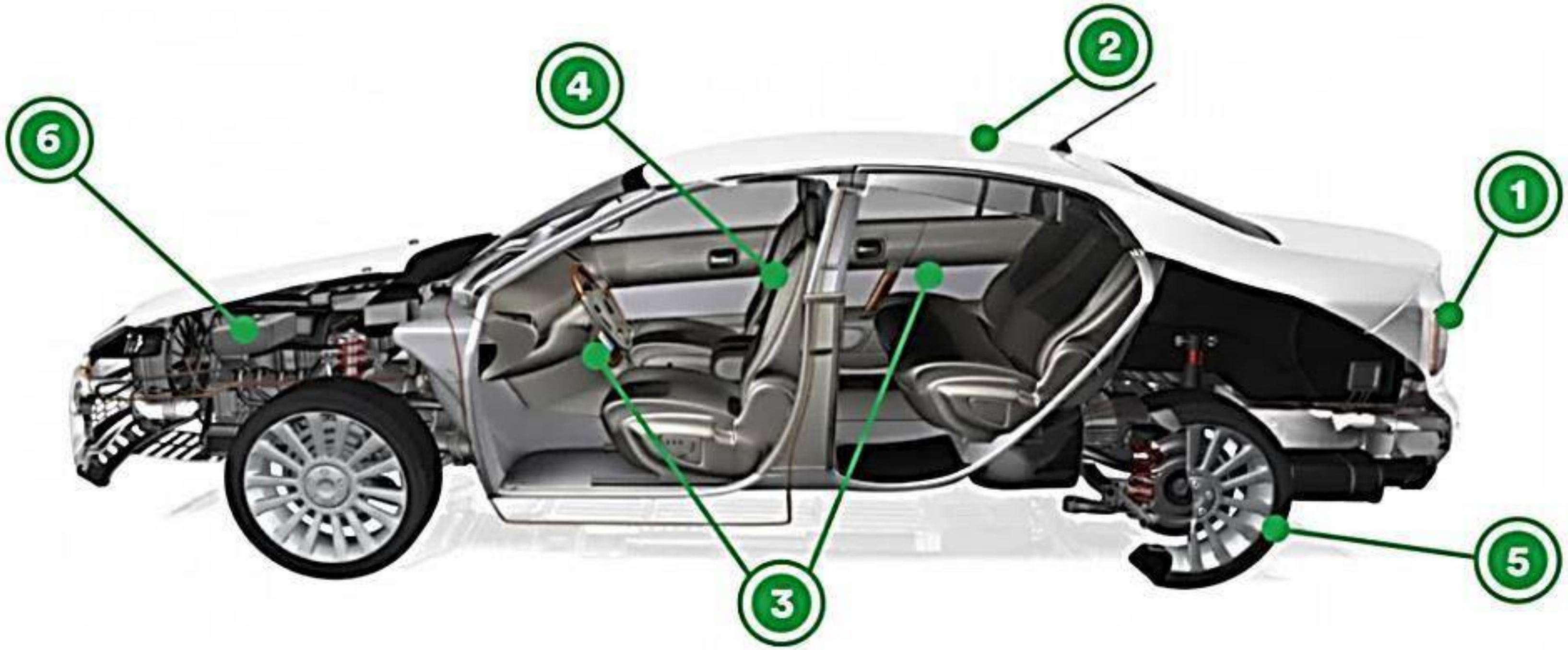
AI Design
Material optimization

Net-Zero
Factory operations

Projected Adoption of Sustainable Materials by 2030.



Overview of Innovative Sustainable Materials in Automotive Manufacturing



1 Exterior Components
- Abaca fibers and kenaf in spare tire covers
- Coffee chaff in headlamp housings
- Coatings derived from biomass
- Soy in exterior mirrors

3 Interior Components
- Bamboo in deco trim
- Cellulose tree-fibers in armrests
- Coconut fibers in load floors
- Cotton fibers in sound insulators
- Kenaf, hemp and sisal in door panels
- Soybeans in foams
- Wheat straw in storage bins

5 Tires(& Rubber Components)
- Carbon black from renewable natural gas feedstock
- Dandelion-derived natural rubber
- Rise and husk silica
- Soybean oil

2 Headliners
- Cotton and kenaf in acoustic insulation
- Hemp and kenaf in sunroof frames
- Soybeans in frames

4 Seating
- Cellulose tree-fibers in textiles
- Responsibly sourced wool in covers
- Soybeans in foams
- Sugarcane in seat cushions

6 Underhood Components
- Castor oil in fuel lines and radiator tanks
- Flax in engine covers
- Rice hulls in electrical harness

Emerging Bio-Materials

Algae-Based Composites

Algae biomass offers rapid growth and carbon capture capabilities. Being developed for interior panels and foam alternatives.

Status: R&D phase

Agricultural Waste

Rice husks, wheat straw, and corn stalks transformed into fiber reinforcements. Reduces agricultural burning emissions.

Status: Pilot production

3D-Printed Biopolymers

Additive manufacturing with bio-based filaments enables complex geometries with zero waste. Custom parts on demand.

Status: Early adoption

Wine Waste Leather

Grape marc from wine production transformed into premium leather alternatives. High-quality finish for luxury interiors.

Status: Commercial launch

Coffee Ground Composites

Spent coffee grounds mixed with biopolymers create unique textures and natural odor absorption properties.

Status: Concept testing

Lab-Grown Materials

Cellular agriculture producing collagen and other proteins for leather-like materials without animal farming.

Status: Research phase

Innovation Pipeline

AI-driven material discovery accelerating development cycles from years to months

2030

Target: 40% sustainable materials


Recycle
Renew
Reuse
Restore