GREEN MOBILITY ENERGIZED BY

Green Tires Fact Book
Agenda

1. LANXESS – committed to global megatrends
2. The need for CO₂ emission reduction – EU leading the way
3. Tire basics and the role of rubber
4. The environmental benefits of “Green Tires”
5. “Green Tires” meeting consumer expectations
6. An emerging global market for “Green Tires”
7. LANXESS – a key enabler of “Green Tires”
LANXESS – a global player in the specialty chemicals industry

**Specialty chemical company**
- Spun-off from Bayer in 2004, listed in the DAX* since 2012
- Focus on: plastics, synthetic rubber, specialty chemicals, intermediates

**Global success story**
- Roughly 17,100 employees in 31 countries
- 49 production sites worldwide
- 2011 sales of EUR 8.8 billion

**Strategy of targeted innovation**
- Vital role in LANXESS’ growth
- Focus on process and product innovation

* German stock market index
LANXESS is Energizing Chemistry

### Premium quality
- Premium specialty chemicals company
- More than 5,000 products for a diverse range of applications
- High quality solutions enabling customers to successfully meet current and future challenges

### Technical expertise
- State-of-the-art materials, services and solutions that meet the most exacting standards
- Creating significant value for our customers, the environment and our company

### Sustainability
- Commitment to sustainable development
- Creation of green solutions to meet the challenges of global megatrends
- Development of environmentally-friendly technologies, resource-efficient processes and next-generation products

### Innovation
- Targeted innovation designed to meet customer needs
- Pragmatic corporate culture drives product, process and outside-the-box innovation
- Highly effective innovation network, combining global reach with local expertise

**LANXESS – global mission**
LANXESS capitalizing on global megatrends

- Mobility
- Agriculture
- Urbanization
- Water
Future challenges drive the need for sustainable mobility

Environment
- Climate protection
- Impact of climate change is significant

Growing mobility
- Among the growing middle class in emerging economies

Economics
- Shortage of resources
- Rising prices for fossil fuels

Urbanization
- Almost 60% of the world's population will live in cities by 2030
- Greater traffic density leads to increased noise emissions

Consumer
- Trend toward a sustainable lifestyle
- Societal demand for environmental stewardship

Politics
- More stringent legislation
  - to protect the environment
  - to reduce emissions and fossil fuel dependency

Source: United Nations, Department of Economic and Social Affairs
LANXESS solutions help people and goods travel quickly, cleanly and safely

<table>
<thead>
<tr>
<th>Lightweight construction</th>
<th>LANXESS high-tech plastics make vehicles lighter, safer and more comfortable</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Green Tires”</td>
<td>LANXESS synthetic rubber blends and additives are key ingredients that allow modern tires to improve performance, save fuel, enhance safety and last longer</td>
</tr>
<tr>
<td>Bio-based raw materials</td>
<td>With innovative products such as Keltan Eco – the first form of bio-based EPDM rubber in the world – LANXESS supports the development of bio-based alternatives to petroleum based materials</td>
</tr>
</tbody>
</table>
1. LANXESS – committed to global megatrends

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Meeting the global climate challenge

Worldwide efforts to reduce CO₂ emissions

Focused country initiatives to reduce energy consumption in key sectors

Construction | Manufacturing | Energy conversion | Mobility

Adoption of regulations and establishment of minimum energy efficiency standards
USA aiming for a CO$_2$ reduction of 17% during the period 2005 - 2020*

Brazil aiming to reduce greenhouse gas emissions by at least 36% below projected 2020 levels

EU aiming for a 20% cut in greenhouse gas emissions during the period 1990 - 2020

China aiming to reduce CO$_2$ emissions by 40-45% compared to economic growth during the period 2005 - 2020

Japan promising a 25% cut in CO$_2$ emissions by 2020 if all major economies participate

South Korea planning to reduce emissions by 30% below projected 2020 levels (4% below 2005 values)

India seeking to reduce CO$_2$ emissions by 20-25% compared to economic growth during the period 2005 - 2020

Source: United Nations Framework Convention on Climate Change (UNFCCC) * Provided that the awaited law on climate control comes into effect as scheduled
EU – a clear commitment to increased energy efficiency

EU Energy Efficiency Plan

- Increasing energy efficiency to boost sustainable growth and competitiveness
- EU strategy focused on
  - enforcement of existing legislation
  - development of innovative solutions

Key objectives for 2020 (compared to 1990)

- Cutting energy consumption by 20%
- Reducing annual greenhouse gas emissions by 740 million tons
- Cutting energy costs by EUR 100 billion per year

Traffic forms a substantial part of the EU Efficiency Plan

Key Facts
- 18% of global CO₂ emissions are related to traffic
- In the EU, transport is the only economic sector which CO₂ emissions are constantly increasing, especially in those segments involved in vehicular transportation

EU Objective by 2012 (compared to 2006)
- Lowering average CO₂ emissions for newly-registered vehicles from 160 g/km to 130 g/km by 2015 and to 95 g/km by 2020
- Of that, 10 g/km is to be achieved through measures not directly linked to fuel combustion (e.g. tires)

Modern tires improve energy efficiency in traffic

Key Facts
- 20-30% of a vehicle’s fuel consumption is related to tires
- 24% of a vehicle’s CO₂ emissions are related to tires

New EU regulations aim to
- Improve energy efficiency and safety standards of future tires
- Enable consumers to make informed purchasing decisions

Sources: BMW, Der Reifen im Spannungsfeld zwischen hohen technischen Anforderungen und immer schärfer werdenden gesetzlichen Auflagen, 2008
Michelin, CO₂ Reduzierung – Ein Beitrag der Reifenindustrie, 2008
Establishes uniform requirements for the type approval of new tires (categories C1 – C3*) across the EU with regard to
- safety (wet grip)
- rolling resistance
- rolling noise
Introduction of new limit values for type approval of tires in November 2012
As of November 2014 all new vehicles must be equipped with type approved tires and only these can be sold on the replacement market

### Limit values for the safety aspect of wet grip

<table>
<thead>
<tr>
<th>Usage category</th>
<th>Limit value (G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M+S tires with a maximum permissible speed of 160 km/h</td>
<td>0.9</td>
</tr>
<tr>
<td>M+S tires with a permissible speed above 160 km/h</td>
<td>1.0</td>
</tr>
<tr>
<td>Normal tires</td>
<td>1.1</td>
</tr>
</tbody>
</table>

### Limit values for rolling resistance

<table>
<thead>
<tr>
<th>Tire category</th>
<th>Phase 1 (as of 2012)</th>
<th>Phase 2 (as of 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>12</td>
<td>10.5</td>
</tr>
<tr>
<td>C2</td>
<td>10.5</td>
<td>9.0</td>
</tr>
<tr>
<td>C3</td>
<td>8.0</td>
<td>6.5</td>
</tr>
</tbody>
</table>

* C1: tires according to ECE R 30 (cars)
  C2: tires according to ECE R 54 (light trucks)
  C3: tires according to ECE R 54 (heavy duty vehicles)
EU tire labeling – enables consumers to make informed purchasing decisions

- Tire labeling aims to improve safety, ecological and economical efficiency of road traffic
- The label informs consumers about key tire performance parameters
  - impact on fuel efficiency associated with rolling resistance
  - impact on safety associated with wet grip
  - external noise level
- Tire labeling becomes mandatory from November 2012, meaning that all tires* produced as of July 2012 must have the label


* Passenger car, light truck and heavy duty vehicle tires
Wet grip is one of the most important safety characteristics of a tire. Tires with excellent wet grip have a shorter braking distance in rainy weather. “A”-rated tires provide the most wet grip, while “F”-rated tires provide the least. For example: an “F”-rated tire needs an additional 18 to 21 meters to come to a standstill from a speed of 80 km/h compared to an “A”-rated tire.

Source: Continental

* Actual braking distance may vary according to road surface and vehicle

** Class D and G are not defined
A vehicle’s fuel consumption is affected by the rolling resistance* of its tires.

By reducing rolling resistance, a tire can improve fuel efficiency of a car.

For example, the difference between a “C”- and a “B”-rated car tire translates into a change in fuel consumption of ~2.5%

Source: Continental

* The impact of rolling resistance on engine performance is explained in detail on page 40
** Class D only applies to truck tires
*** For more information and to download the app, visit http://save-fuel.lanxess.com
The label describes the level of external noise generated by the tire (not the internal noise heard by the car’s occupants)

External noise level is expressed in decibels (dB), and indicated by one, two or three sound waves

For example: one black wave indicates optimal noise level performance (3 dB below the new EU limit*), while three black waves indicate the highest noise level (tire is in compliance with old EU limit)

Source: Continental

* The new European tire external noise levels will be introduced by 2016
Emergence of worldwide adoption of tire regulations and implementation of tire labeling

Preliminary tire labeling proposed by NHTSA in March 2010 – earliest expected implementation in 2014

Mandatory tire labeling for all new tires on sale as of November 2012

Due to its rapidly increasing mobility, China will inevitably need regulations in the near future; promotion of “Green Tires” part of new 5 Year Development Plan

Voluntary tire labeling standards in place since 2010

Implementation of mandatory energy efficiency label for tires as of October 2016

Mandatory tire labeling since December 2012
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Tires are an essential part of each vehicle

- A tire fulfills multiple important functions
  - supporting the weight of the vehicle
  - absorbing shocks from the road
  - transmitting the power to accelerate, brake and steer on the road
  - maintaining and changing direction

- A tire should meet certain criteria
  - safety (dry/wet conditions, high speeds, braking)
  - comfort (shock absorption, noise)
  - fuel economy
  - durability

Basic function of key tire parts

Carcass
Carrying the weight of the car

Tread
Directing and transferring all forces generated by the vehicle

This and other criteria are constantly tested by associations and trade magazines*

- Safety
- Comfort
- Fuel economy
- Durability

Source: Michelin; Hankook; Allgemeiner Deutscher Automobil-Club e.V. (ADAC)
* Test representatives include ADAC, Austrian Auto Motor and Touring Club (ÖAMTC), Touring Club Switzerland (TCS), AutoBild, Auto Motor und Sport, and others
Where tire and road surface meet

- Tires are the only part of the vehicle in contact with the road
- Each tire’s contact patch*, or footprint, is only about the size of a postcard
- The distribution of pressure across a tire’s footprint differs depending on rolling speed
- With increasing speed, the shape of the footprint changes from a circle to a square
- At moderate speed, energy loss (in the form of heat) occurs primarily in the tire tread
- At highway speed, energy loss occurs primarily in the sidewalls and inner liner

Tire structure is key to the even distribution of vehicle load across the tire footprint

Contact patch with road is about the size of a postcard

Source: Automobilwoche

* Area of tread in contact with the road surface
A tire consists of eight different layers

- **Tread** ➔ *Influences grip, fuel economy and noise*
- **Undertread** ➔ *Joins the tread to steel belt and carcass*
- **Upper steel belt** ➔ *Influences driving features and shape*
- **Sidewall** ➔ *Protects carcass and influences fuel economy*
- **Lower steel belt** ➔ *Influences driving features and shape*
- **Carcass** ➔ *Gives support and shape*
- **Innerliner** ➔ *Replaces the tube*
- **Steel wires** ➔ *Keeps the tire safely attached to wheel rim*
All layers must meet certain requirements

<table>
<thead>
<tr>
<th>Layer</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tread</strong></td>
<td>- High energy and low energy losses for traction and rolling resistance</td>
</tr>
<tr>
<td></td>
<td>- High abrasion resistance</td>
</tr>
<tr>
<td><strong>Undertread</strong></td>
<td>- High stiffness</td>
</tr>
<tr>
<td></td>
<td>- Low rolling resistance</td>
</tr>
<tr>
<td><strong>Upper steel belt/Lower steel belt</strong></td>
<td>- Must be dent-resistant while simultaneously allowing the tire to remain flexible</td>
</tr>
<tr>
<td><strong>Sidewall</strong></td>
<td>- Must be able to easily change shape</td>
</tr>
<tr>
<td></td>
<td>- High resistance to flex cracking and fatigue as well as low heat build-up required</td>
</tr>
<tr>
<td><strong>Carcass</strong></td>
<td>- High strength and fatigue resistance</td>
</tr>
<tr>
<td></td>
<td>- Compound needs to stick well to carcass cords</td>
</tr>
<tr>
<td><strong>Innerliner</strong></td>
<td>- Must be particularly impermeable to air</td>
</tr>
<tr>
<td><strong>Steel wires</strong></td>
<td>- Must provide good steer response made possible by high strain modulus, maintaining footprint at higher speeds</td>
</tr>
<tr>
<td></td>
<td>- High stiffness, low RRC* and good adhesion to steel cord surface</td>
</tr>
</tbody>
</table>

Source: Michelin Fact Book 2003
U.S. Department of Transportation

* Rolling resistance coefficient
Rubber is the main ingredient in tires

- While more than 200 individual ingredients can go into a modern passenger car tire, most of them fall within one of three main categories that affect a tire’s performance profile:
  - rubber (natural, synthetic)
  - fillers* (carbon black, silica, etc.)
  - additives** (vulcanizing agents, vulcanizing accelerators, antioxidants, softeners, waxes for light protection, etc.)
- Today, the mix of natural (14%) and synthetic rubber (27%) accounts for roughly 40% of a modern passenger car tire's total components.

Nearly 1/3 of a passenger car tire consists of synthetic rubber.

Source: Washington State Department of Ecology/Rubber Manufacturers Association; Continental

* These reinforce rubber compounds; they include active fillers (strengthening the rubber) and inactive fillers (making the rubber go further).
** Processing aids, which affect the final properties of the end product.
## Natural rubber and synthetic rubber

<table>
<thead>
<tr>
<th>Natural rubber</th>
<th>Synthetic rubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Derived from latex, a milky white fluid collected from rubber trees in tropical plantations</td>
<td>- Oil is the most common raw material for synthetic rubber production</td>
</tr>
<tr>
<td>- One of the most elastic types of rubber</td>
<td>- Mechanical production based on chemical processes</td>
</tr>
<tr>
<td>- Resistant to wear and fatigue</td>
<td>- Highly resistant to abrasion and oxidation</td>
</tr>
<tr>
<td>- Only moderate resistance to damage from exposure to heat and light</td>
<td>- Superior resistance to heat</td>
</tr>
<tr>
<td>- Global production increased by 7%, from 9,690,000 tons in 2009 to 10,399,000 tons in 2010</td>
<td>- Contamination-proof</td>
</tr>
<tr>
<td></td>
<td>- Global production increased by 14%, from 12,385,000 tons in 2009 to 14,082,000 tons in 2010</td>
</tr>
</tbody>
</table>

Source: Trelleborg International Rubber Study Group (IRSG)
## Different types of synthetic rubber and their role in tires*

<table>
<thead>
<tr>
<th>Rubber</th>
<th>Characteristics</th>
<th>Tire industry applications</th>
</tr>
</thead>
</table>
| Polybutadiene (BR) | ▪ Reduced heat build up  
▪ High abrasion resistance  
▪ Improved fatigue properties | ▪ Tread  
▪ Sidewall  
▪ Carcass |
| e.g. neodymium polybutadiene rubber (Nd-PBR) | ▪ Outstanding abrasion resistance  
▪ Excellent strength  
▪ High crack resistance | |
| Styrene-butadiene rubber (SSBR) | ▪ Moderate abrasion resistance  
▪ Good mechanical properties | ▪ Tread |
| Butyl rubber (IIR) | ▪ Good resistance to acids, hot water, etc.  
▪ Excellent impermeability | ▪ Inner tubes for tires  
▪ Bladders for tire manufacture |

* See benefits on pages 69 et seq.
The production of synthetic rubber

**Production of synthetic rubber**

1. **Extraction from raw material feedstocks**
   - In a refinery, monomers* are extracted from oil
   - Liquid monomers are generally made from ethyl benzene
   - Gas monomers are usually obtained by using heat to break up the molecules in the presence of a catalyst

2. **Polymerization**
   - Monomer molecules are brought together through a chemical reaction to form polymer chains

3. **Separation**
   - The polymer is isolated from the solution medium in the form of crumbs

4. **Compression**
   - Crumbs are washed, dried and pressed into bales

**Monomers**
- Gas
- Liquid

**Polymers**
- Synthetic rubber

**Synthetic rubber bales**
- The raw rubber in plastic form is shipped to tire manufacturers

Source: International Rubber Study Group (IRSG)

* A molecule that forms the basic unit for polymers
**The production of tires**

### Semi-finished products are manufactured

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Up to 12 different rubber compounds are blended together in a kneader</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>The blended rubber material is shaped into an endless tread strip by means of an extruder</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Rubberized steel cord fabric is cut and assembled into a single, continuous strip</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>For the textile layer, a sheet of fabric is embedded within a layer of rubber and cut into varying widths and angles</td>
</tr>
</tbody>
</table>

### Building and vulcanization*

<p>| | |</p>
<table>
<thead>
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<tbody>
<tr>
<td><strong>5</strong></td>
<td>The individual semi-finished products are assembled into a tire blank</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>&quot;Baked&quot; in a heating press, the plastic, raw rubber is vulcanized into elastic rubber, thus combining the different components of the tire into its final shape</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>After visual inspection and uniformity checks, the tire is ready for shipment</td>
</tr>
</tbody>
</table>

*Vulcanization takes place at 140-200°C in a process determined by time, temperature and pressure.*

Source: Continental
Consumers can prevent tire failure – by making the right tire choices

- Optimal road holding in wet, slippery or winter conditions can be assured by different tire types
- Summer tires perform best in warm weather
- Winter tires perform best in severe winter conditions
- Due to the cold temperatures, winter tires are comprised of more flexible rubber compounds
- In snow, a vehicle with summer tires needs almost twice as much distance to come to a full stop
- All-season tires provide reliable performance in warm and moderate winter conditions
- Mud and snow (M&S) tires have higher void ratios to channel away rain, mud and snow

Matching tires to prevailing weather conditions is essential for safety.
Consumers can prevent tire failure – by checking the DOT code on their tires to determine their age

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The DOT code is an alphanumeric sequence that is printed on the side of a tire to show its age, size, brand and origin

- The first two characters indicate the plant code
- The third and fourth characters represent the tire size
- The last four numbers represent the week and year the tire was built
- The technical properties of a tire deteriorate over time
- When buying a car, a tire should be not older than three years

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<table>
<thead>
<tr>
<th>DOT</th>
<th>2X</th>
<th>13</th>
<th>CJ H</th>
<th>10</th>
<th>09</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant code</td>
<td>Size</td>
<td>Brand code*</td>
<td>Week</td>
<td>Year</td>
<td></td>
</tr>
</tbody>
</table>

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The DOT code provides technical information on the tire

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Source: Allgemeiner Deutscher Automobil-Club e.V. (ADAC)

* Identification of brand as well as other characteristics important to manufacturers; number of characters between tire size and the final four characters may vary
Consumers can prevent tire failure – by regularly checking their air pressure and adjusting it accordingly

- Improper air pressure contributes to tire failure (e.g. tread separation, blowouts, flat tires)
- It also negatively influences rolling resistance*
- For example, a tire with air pressure of roughly 1 bar below recommended levels results in a more than 30% increase in rolling resistance
- Additionally, this deficiency causes a car to burn an extra 0.5 liters of fuel per 100 km
- Therefore, not only does improper air pressure increase safety risks but also fuel consumption and CO₂ emissions

* Rolling resistance is the energy that is lost when the tire is rolling; the main reason for the loss of energy is the constant deformation of the tire
Consumers can prevent tire failure – by measuring tire tread depth

- Sufficient tread depth is vital, even at low speeds
- Decreased tread depth reduces comfort, grip, traction and braking
- Legal minimum tread depth standard is 1.6 mm**
- Recommended minimum tread depth is 3 mm***
- Tread depth measurements can be taken with €1 coin (yellow rim should entirely fit into the tread grooves)
- Grooves are a key feature of the tread pattern; over decades, they have been continuously optimized
- Today, innovative tires that feature asymmetrical tread designs also assist in noise reduction

Regularly checking tread depth is key to safety

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* Summer tire, braking from 100 km/h to 60 km/h  ** Adopted as a regulation by many of the world’s national transportation authorities
*** Recommended by major European car manufacturers
The history of tires – the long journey to the modern tire

- **1844**: Charles Goodyear invents vulcanized rubber, which later becomes a key ingredient for tires
- **1888**: John Dunlop invents the air-filled or pneumatic* tire for bicycles
- **1895**: Michelin introduces the first pneumatic automobile tire
- **1904**: Grip-Tread pattern for pneumatic tires is introduced
- **1909**: Synthetic rubber is invented by chemist Fritz Hofmann of Elberfelder Farbenfabriken, one of the antecedents of LANXESS
- **1910**: Carbon black** is added to white rubber
- **1946**: Michelin introduces the radial tire***, which is still in use
- **1972**: DuPont invents a polyamide fiber called Kevlar – a replacement for steel in racing tires
- **1977**: Goodyear introduces year-round, all-weather tires
- **1992**: Michelin incorporates silica into tire rubber compounds

* Filled with (compressed) air  ** Reinforcing filler that blackens rubber and gives it strength  *** Featuring body ply cords that are laid radially from bead to bead, nominally at 90° to the centerline of the tread. Two or more belts are laid diagonally in the tread region to add strength and stability
Until today, overall tire performance improved significantly

- As a result of the continuous development of innovative technologies and materials, modern high-quality tires offer exceptional performance in all areas of measurement.
- Since 1975, tire manufacturers have managed to optimize all key tire parameters by at least 25%, e.g.
  - rolling resistance
  - handling
  - dry traction
  - wet traction
  - hydroplaning
  - durability

Source: Continental AG
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“Green Tires” contribute to sustainable mobility by increasing fuel efficiency and reducing greenhouse gas emissions in road traffic. Simultaneously, “Green Tires” offer excellent safety and driving features.

- Reduced fuel consumption by 5% to 7%
- Reduced CO$_2$-emissions by 1.2 kg/100 km*
- Shorter braking distance at 80km/h by up to 21 meters compared to normal tires
- Extra costs amortized within one to two years**

* Calculation based on a car with a gasoline engine and an average fuel consumption of 10 L/100 km
** Depending on distance driven
Tires have the highest environmental impact when they are in use on the road

- The biggest share of environmental pollution related to tires is created during road use, in total 86%
  - tire wear/particulate matter from abrasion accounts for roughly 10%
  - 76% of the adverse environmental impact of tires can be traced back to fuel consumption (and the associated emissions) during usage

Source: Michelin Fact Book 2003
**Environmental impact of “Green Tires”**

<table>
<thead>
<tr>
<th><strong>“Green Tires” are vital for sustainable future mobility</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>(Calculation based on a car with a gasoline engine and an average fuel consumption of 10 L/100 km)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reduced rolling resistance</th>
<th>-30 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced fuel consumption</td>
<td>-0.5 l/100 km</td>
</tr>
<tr>
<td>Reduced CO₂ emissions</td>
<td>-1.2 kg/100 km</td>
</tr>
</tbody>
</table>

**Improved environmental impact**

During travel, the tire deforms to absorb road surface irregularities – it is because it can change shape that it provides grip and comfort.

As the rubber compounds are deformed, they heat up and dissipate part of the energy transmitted by the engine – a phenomenon known as rolling resistance.

On average, 20-30% of fuel consumption is used to overcome rolling resistance, while the rest of the fuel consumed serves to counter air resistance, inertia and inner friction (e.g. in the engine or transmission).

“Green Tires” with lower rolling resistance help to reduce fuel consumption.

Sources: BMW, Der Reifen im Spannungsfeld zwischen hohen technischen Anforderungen und immer schärfer werdenden gesetzlichen Auflagen, 2008
Michelin Fact Book 2003
ADAC, www.adac.de/infotestrat/reifen/rollwiderstand.aspx
Passenger cars are responsible for
- roughly 12% of total CO₂ emissions in the EU
- roughly 5% of man-made CO₂ emissions globally – this is on the rise

A reduction of road traffic emissions – especially in developed countries – would have a significant effect on the overall CO₂ balance

Rolling resistance and fuel consumption have an immediate impact on CO₂ emission

Fuel-efficient “Green Tires” help to reduce road-traffic-related CO₂ emissions

Sources: ec.europa.eu/clima/policies/transport/vehicles/cars_en.htm
Traffic noise is by far the biggest source of noise pollution.

An overall increase in traffic has offset continuous reductions in noise pollution across the automotive sector.

Road traffic noise consists primarily of propulsion noise (engine, exhaust systems etc.) and rolling noise (tire-road interaction).

The vast array of preventive and remedial measures includes tire and engine technologies, road surfacing and traffic management strategies.

At 33%, traffic noise represents the biggest source of noise pollution in Germany.

Quiet tires with innovative tread patterns and optimized rubber composites help to reduce rolling noise emissions.

Sources: www.nynas.com/templates/Page_9037.aspx?epslanguage=EN
www.iproplan.de/cms/images/stories/pdf/10_03.pdf
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“Green Tires” meet diverse consumer demands

- High safety standards
- Reduced environmental impact
- Greater durability
“Green Tires” – improving safety standards

<table>
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<tr>
<th>Safety</th>
<th>Sustainability</th>
<th>Durability</th>
</tr>
</thead>
</table>

**Safety comes first**

- Safety ranks as the most important parameter for drivers
- “Green Tires” offer excellent performance in traction, handling and wet grip
- Wet grip of tires is a key factor for safety
  - “Green Tires” guarantee a better wet road grip and thus a shorter braking distance than regular tires
  - New EU tire labeling informs customers of the important safety aspect of wet grip performance and helps set the right priorities in the purchasing process
“Green Tires” – providing better environmental protection

<table>
<thead>
<tr>
<th>Safety</th>
<th>Sustainability</th>
<th>Durability</th>
</tr>
</thead>
</table>

**Growing societal demand for environmental stewardship**

- High consumer demand for sustainable mobility driven by
  - increased traffic volume
  - the high price of fossil fuels
  - increased environmental awareness

- “Green Tires” allow every driver to make a personal contribution to improving the energy efficiency of automobiles and to protect the environment

- Fitting all vehicles worldwide with “Green Tires” could result in annual savings of around 20 billion liters of fuel and nearly 50 million metric tons of CO$_2$ emissions

Source: Michelin
“Green Tires” – increasing mileage and service life

Enhancing ride quality and mileage
- Raising consumer demand for driving comfort and tire durability due to
  - increasing personal mobility
  - longer travel distances and higher mileage
  - growing cost sensitivity
- “Green Tires” provide enhanced mileage and longer service life, resulting in
  - better price-performance ratio
  - conservation of environmental resources
  - reduced particulate matter from tire abrasion
  - less tire waste
“Green Tires” – a worthwhile investment

- While “Green Tires” may cost a little more up front, they reduce fuel consumption by 5% to 7%.
- Consumers will benefit in the long run from better fuel economy, translating into savings at the gas pump.
- *Example:* A person traveling 12,500 km per year could easily save up to 100 EUR of fuel each year. The additional investment of 20 to 50 EUR per tire is amortized within two years.
“Green Tires” that combine efficiency and safety are already a reality

<table>
<thead>
<tr>
<th>Brand</th>
<th>Model</th>
<th>Reduced Rolling Resistance</th>
<th>Reduced Wet Braking Distance</th>
<th>Improved Mileage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pirelli</td>
<td>Cinturato P1</td>
<td>25%*</td>
<td>3%*</td>
<td>30%**</td>
</tr>
<tr>
<td>Bridgestone</td>
<td>Ecopia EP 150</td>
<td>15%*</td>
<td>5%*</td>
<td>15%*</td>
</tr>
<tr>
<td>Continental</td>
<td>Ecocontact 5</td>
<td>20%*</td>
<td>10%*</td>
<td>12%*</td>
</tr>
<tr>
<td>Goodyear</td>
<td>EfficientGrip</td>
<td>15%***</td>
<td>3%***</td>
<td>3%***</td>
</tr>
<tr>
<td>Michelin</td>
<td>Energy Saver</td>
<td>20%*</td>
<td>8%*</td>
<td>40%***</td>
</tr>
<tr>
<td>Hankook</td>
<td>Kinergy Eco</td>
<td>15%*</td>
<td>12%*</td>
<td></td>
</tr>
</tbody>
</table>

* Compared to their predecessors  
** Compared to ordinary tires  
*** Compared to the average performance of leading competitors’ tires

Sources: Pirelli; Bridgestone; Continental; Goodyear; Michelin; Hankook
Agenda

1. LANXESS – committed to global megatrends
2. The need for CO2 emission reduction – EU leading the way
3. Tire basics and the role of rubber
4. The environmental benefits of “Green Tires”
5. “Green Tires” meeting consumer expectations
6. An emerging global market for “Green Tires”
7. LANXESS – a key enabler of “Green Tires”
Increasing worldwide demand for mobility

- Rising worldwide prosperity, particularly in China and India
- Enables an increasing number of new middle-class families to achieve personal mobility
- Millions of trade-ups to be realized soon
  - bicycles for mopeds
  - mopeds for cars
- Leading to increased car ownership, especially in Asia

Future mobility demand driven by emerging Asian middle class

Sources: Goldman Sachs Global Economics Group. "Is this the BRICs decade?", 2010
Michelin estimates
* Population with income >$6,000 and <$30,000/capita in BRIC countries
New tire regulations will lead to a polarized tire market

Growing demand for high-performance premium brands

Source: Exane BNP Paribas estimates

* Global tire related regulations (EU, Japan, South Korea, etc.)
By 2015, the high-performance tire segment will have increased by 77%.

Rolling-resistance-optimized tires are expected to replace regular tires and become the standard in Europe.

The implementation of new EU regulations will challenge the global rubber, tire and automotive industries to adapt their products and processes to the CO₂ emission requirements.

LANXESS offers the right products for “Green Tires”
1. LANXESS – committed to global megatrends
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7. LANXESS – a key enabler of “Green Tires”
Expertise and innovation are key elements for sustainable development

<table>
<thead>
<tr>
<th>Driving sustainable mobility...</th>
<th>…through continuous development</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ LANXESS has more than 100 years of experience in the development and production of synthetic rubber and rubber chemicals</td>
<td></td>
</tr>
<tr>
<td>▪ LANXESS sets the pace in the field of performance rubbers by constantly developing new innovative products</td>
<td></td>
</tr>
<tr>
<td>▪ Half of LANXESS’ sales to the rubber industry are to tire manufacturers</td>
<td></td>
</tr>
<tr>
<td>▪ LANXESS is clearly focused on products for “Green Tires”</td>
<td></td>
</tr>
</tbody>
</table>
LANXESS is committed to products for tires

R&D
- Focusing on product innovations that enable our customers to create safe, durable, and fuel-saving tires that meet the challenges of growing mobility worldwide

Production facilities
- Expanding rubber production capacities to serve growing demand
- Construction of the world’s largest Nd-PBR plant in Singapore by 2015

Technical support
- Technical experts in the rubber business units support our most exacting customers with state-of-the-art services and solutions that bring significant value to their business
LANXESS sites worldwide providing products for “Green Tires”
LANXESS offers the broadest portfolio of synthetic rubbers and additives in the industry (1/2)

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Tire</th>
<th>Technical Rubber Products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBR</td>
<td>BR</td>
</tr>
<tr>
<td><strong>LANXESS</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>POLIMERI EUROPA</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>DUPONT</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Dow</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Exxon</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>JSR</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td><strong>Zeon</strong></td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
LANXESS offers the broadest portfolio of synthetic rubbers and additives in the industry (2/2)

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Accelerators</th>
<th>Antidegradants</th>
<th>Special Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CBS</td>
<td>TBBS</td>
<td>DCBS</td>
</tr>
<tr>
<td>LANXESS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FLEXSYS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SINORGCHEM</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>China Sunine Chemical Holdings Ltd.</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Kemal</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>KUMHO PETROCHEMICAL</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>GENERAL QUINCA</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ISTROCHEM DUSLO</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>蒙汉磷河化工有限公司</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

* General abbreviation does not exist yet
** Product under development
### Tire Components and Functions

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tread</td>
<td>Influences grip, fuel economy and noise</td>
</tr>
<tr>
<td>Undertread</td>
<td>Joins the tread to steel belt and carcass</td>
</tr>
<tr>
<td>Upper steel belt</td>
<td>Influences driving features and shape</td>
</tr>
<tr>
<td>Sidewall</td>
<td>Protects carcass and influences fuel consumption</td>
</tr>
<tr>
<td>Lower steel belt</td>
<td>Influences the driving features and shape</td>
</tr>
<tr>
<td>Carcass</td>
<td>Gives support and shape</td>
</tr>
<tr>
<td>Innerliner</td>
<td>Replaces the tube</td>
</tr>
<tr>
<td>Steel wires</td>
<td>Keeps the tire safely attached to wheel rim</td>
</tr>
</tbody>
</table>

**Energized by LANXESS rubber and additives**
High-end rubbers needed to improve tire efficiency

Proportion of tire components in rolling resistance

LANXESS solutions to increase tire performance

Effect of LANXESS high-end rubbers in treads

Source: BMW, Der Reifen im Spannungsfeld zwischen hohen technischen Anforderungen und immer schärfer werdenden gesetzlichen Auflagen, 2008
### Synthetic rubbers – more than just increased efficiency

#### Characteristics of “Green Tires”: LANXESS products

<table>
<thead>
<tr>
<th>Feature</th>
<th>LANXESS Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized microstructure and filler interaction</td>
<td>S-SBR Nd-PBR Nanoprene</td>
</tr>
<tr>
<td>→ Fuel economy</td>
<td></td>
</tr>
<tr>
<td>Long chains (physical network)</td>
<td>Nd-PBR</td>
</tr>
<tr>
<td>→ Crack resistance</td>
<td></td>
</tr>
<tr>
<td>Flexible chains</td>
<td>Nd-PBR Co-BR</td>
</tr>
<tr>
<td>→ Elasticity</td>
<td></td>
</tr>
<tr>
<td>High hardness</td>
<td>coupled Li-BR</td>
</tr>
<tr>
<td>→ Wear resistance</td>
<td></td>
</tr>
</tbody>
</table>

- **Optimized microstructure and filler interaction → Fuel economy**: This feature optimizes the tire's microstructure, improving fuel efficiency by enhancing the interaction between fillers and the rubber matrix.
- **Long chains (physical network) → Crack resistance**: Long chains within the tire's rubber network contribute to enhanced crack resistance, ensuring durability under various conditions.
- **Flexible chains → Elasticity**: Flexible chains in the tire's structure enhance elasticity, providing a smoother ride and better handling.
- **High hardness → Wear resistance**: High hardness materials reduce wear resistance, ensuring prolonged tire life and reduced maintenance costs.
LANXESS premium products for “Green Tires” – Solution-styrene-polybutadiene rubber (S-SBR)

**Characteristics**
- High density of anchor points that stick particularly well to the hard filler particles → excellent bonding to silica
- Covering of the silica particles with a thick, friction-reducing rubber skin → reduction of the internal friction of the reinforcing silica particles

**Benefits**
- Optimized rolling resistance → increase in fuel efficiency and reduction of CO₂ emissions
- Outstanding road grip → enhanced safety
- Very long service life → improved mileage

**Main brand**
X Buna® VSL
LANXESS premium products for “Green Tires” – Neodymium polybutadiene rubber (Nd-PBR)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest stereoregularity, narrowest molecular weight distribution and least branching within group of high cis-BRs → manufacture of tires with outstanding physical data</td>
<td>Optimized rolling resistance → increased fuel efficiency and reduction of CO₂ emissions</td>
</tr>
<tr>
<td>Very linear and unique macrostructure → lower heat build-up and higher flexibility than other tire elastomers</td>
<td>Excellent resistance to abrasion, flex cracking and fatigue → improved safety and durability</td>
</tr>
<tr>
<td>Strain-induced crystallization → greater resistance</td>
<td></td>
</tr>
</tbody>
</table>

Main brand: Buna® CB
LANXESS premium products for “Green Tires” – Butyl and halobutyl rubber

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Innerliners made of butyl rubber are highly impermeable to air → help prevent under-inflation</td>
<td>▪ Optimized rolling resistance → increased fuel efficiency and reduction of CO₂ emissions</td>
</tr>
<tr>
<td>▪ Butyl rubber in tread compounds → softer tires and better grip and comfort</td>
<td>▪ Improved wet traction → greater safety</td>
</tr>
</tbody>
</table>

Main brands: Butyl®, Chlorobutyl®, Bromobutyl®
LANXESS premium products for “Green Tires” – Nanoprene

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Consists of particles of only around 50 nanometers made from polymerized styrene and butadiene – i.e. “traditional” tire rubber raw materials → minimal size</td>
<td>▪ Enhanced road grip → greater safety</td>
</tr>
<tr>
<td>▪ Nanoparticles with a swell-resistant, highly cross-linked core have special “anchor points” on their surface → Nanoprene particles can be perfectly linked with silica and silanes</td>
<td>▪ Significant improvement in abrasion resistance → increased tire lifespan/mileage and reduced rubber particle emissions</td>
</tr>
</tbody>
</table>
LANXESS premium products for “Green Tires” – Sulfenamides for sulfur cross-linking

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Highly effective accelerator of vulcanization</td>
<td>• Outstanding scorch safety and fast vulcanization time</td>
</tr>
<tr>
<td>➔ better kinetics and network establishment</td>
<td>➔ optimized safe and short tire curing</td>
</tr>
</tbody>
</table>

Main brand: **Vulkacit®** CZ / NZ / DZ / MOZ
**LANXESS premium products for “Green Tires” – Phenylendiamines and quinoline as antidegradants**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
<th>Main brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Protection of rubber goods against oxygen, ozone, fatigue cracking and rubber poison → manufacture of tires with good aging resistance</td>
<td>▪ Protection against fatigue and ozone, prevention of aging and improved service life of tires</td>
<td><strong>Vulcanox® 4020 / 4010 NA / 4030 / 3100 / HS</strong></td>
</tr>
</tbody>
</table>

- Technologically and economically superior antidegradants for rubber particles → improved service life of tires

![Tire diagram with sections: Tread, Sidewall, Undertread, Carcass, Innerliner]
LANXESS premium products for “Green Tires” – Peptizer for mastication of natural rubber

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
<th>Main brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Reduction of molecular weight of natural rubber → improved processing and blending of mix</td>
<td>▪ Reduction of total mixing energy → lower energy required for processing of tires</td>
<td>▪ Renacit® 10 / 11 / 9203</td>
</tr>
</tbody>
</table>
LANXESS premium products for “Green Tires” – Antireversion agents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved stability of network → maintaining physical tire characteristics</td>
<td>Slower reversion of tread compound → more constant tire performance over the entire life of the tire</td>
</tr>
<tr>
<td>Introduction of hybrid cross-links during vulcanization or repairing network during service life → improved service life of tires</td>
<td>Lower rolling resistance and DPG replacement possible → reduced fuel consumption and almost no aniline (carcinogenic) emission</td>
</tr>
</tbody>
</table>

Main brands

- **Vulcuren®**
- **Perkalink® 900**
LANXESS premium products for “Green Tires” – Processing additives for silica compounds

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Processing additives to reduce compound viscosity without reducing crosslinking density and hardness of the vulcanisate</td>
<td></td>
</tr>
<tr>
<td>▪ Often also the Rheometer behavior is improved (steeper curve with good scorch safety)</td>
<td></td>
</tr>
<tr>
<td>▪ Avoidance of heavy metal zinc in manufacturing for tires → improved environmental friendliness</td>
<td></td>
</tr>
</tbody>
</table>

**Main brand**

Silica Additive 9202
LANXESS premium products for “Green Tires” – Functional additives

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
<th>Main brand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved interaction between silica and polymer</td>
<td>Optimized rolling resistance → increased fuel efficiency and reduction of CO₂ emissions</td>
<td>Vulkalink®</td>
</tr>
</tbody>
</table>
LANXESS premium products for “Green Tires” – Processing agents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Customized processing promoters available for all types of tire related</td>
<td>▪ Improvement in processing properties → higher productivity, lower energy consumption</td>
</tr>
<tr>
<td>compounds, e.g. processing agents specifically developed for use in silica</td>
<td>▪ No adverse effects on the tire’s physical properties → no compromise between savings in production and tire</td>
</tr>
<tr>
<td>treads</td>
<td>performance necessary</td>
</tr>
</tbody>
</table>

Main brands

- Aflux®
- Aktiplast®
### LANXESS premium products for “Green Tires” – Release agents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
<th>Main brand</th>
</tr>
</thead>
</table>
| ▪ Typically adapted to the customer’s specific setup → addresses all release problems of a production process in a tire plant  
▪ Powder release agents for all grades of rubber, including soft and oily synthetic rubber compounds → easy interim storage of rubber sheets and further processing after relevant mixing stages | ▪ Aqueous paints for the inside of tires & bladder coatings → problem-free vulcanization and lower scrap rates  
▪ Semi-permanent bladder coating → longer service life | **Rhenodiv**® |
LANXESS premium products for “Green Tires” – Specialty accelerators

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improves reversion properties in all kinds of rubber grades</td>
<td>DPG replacement in silica formulations → no aniline (carcinogenic) emissions</td>
</tr>
<tr>
<td>Enhance solubility of other accelerators such as benzothiazole sulfenamides or benzothiazoles (when combined) → higher crosslinking efficiency</td>
<td>Exceptionally useful in difficult formulations based on mercaptosilanes → further optimized rolling resistance</td>
</tr>
</tbody>
</table>

Main brand: Rhenocure®
LANXESS premium products for “Green Tires” – Bonding agents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
<th>Main brands</th>
</tr>
</thead>
</table>
| ▪ Ensures reliable bonding of rubber compounds with the textile and steel reinforcing layers of a tire | ▪ Stable RFL dip quality for fabric impregnation → less formaldehyde necessary  
▪ Use in steel cord compounds → consistently high level of rubber to metal bonding in radial tires | Rhenosin®  Rhenogran® |
LANXESS premium products for “Green Tires” – Zinc oxide and crosslinking resin

**Characteristics**
- Provide an excellent solution to challenges involved in producing butyl bladder compounds

**Benefits**
- Resin and ZnO already incorporated into butyl rubber → prevents clumps of resin forming on hot metal surfaces in the internal mixer
- Even dispersion of crosslinking chemicals → higher bladder durability

**Main brand**
Rhenogran® PCZ-70/IIR
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
</tr>
</thead>
</table>
| ▪ Ensure a smooth and efficient tire curing process | ▪ Increased productivity → longer bladder life and shorter cure cycles with high conductive compound  
| | ▪ Better tire finish appearance → innovative bladder venting design and surface finish reduce tire scrap |
LANXESS premium products for “Green Tires” – Overview

<table>
<thead>
<tr>
<th>Tire components</th>
<th>LANXESS products</th>
<th>Synthetic rubber</th>
<th>Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tread</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Under-tread</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Sidewall</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Carcass</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Innerliner</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

LANXESS products: VSL, CB, Silasyn, VT, Vulkacit, Vulkamid, Silicas, Silano,

Synthetic rubber: Vulkasyn 4020, 4010, NA, 4030, 3100, HS

Additives: Silica, Aflux, Aktiplast, Silica Additive 9202, Vulkalink, Aktiplast, Rhenodiv, Rhenocure, Rhenosin, Rhenogran.
LANXESS – for a sustainable future of mobility

Performance rubbers are key to solving demanding tire requirements

LANXESS is the leading supplier of high performance rubbers and additives

LANXESS S-SBR and Nd-PBR for maximum performance

Vast expertise on how future tire generations can help achieve sustainable mobility goals
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