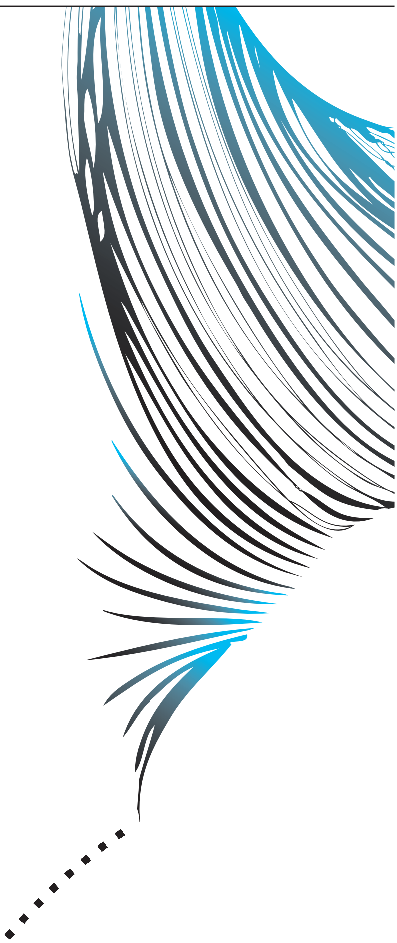
INAUGURAL LECTURE
25 SEPTEMBER 2014



CAN RUBBER HELP AGAINST THE GREENHOUSE EFFECT?

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Inaugural lecture given to mark the assumption of the position as professor of **Elastomer Technology and Engineering** at the Faculty of Engineering Technology at the University of Twente on Thursday 25 September by

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CONTACT TO RUBBER

We are surrounded by rubber products from the very beginning: When we are just born, our first contact to rubber is with a baby bottle nipple. When we start to explore the use of our hands, we play with rubber toys like rubber balls or rubber ducks. When we start to walk, we wear shoes with rubber soles. And when we increase our radius of action, we drive a tricycle or a Bobby-Car with rubber tires. Later we drive a bicycle and finally a car, both of course equipped with rubber tires as well.

This description fits exactly to my vita. I bought my very first car back in 1990, a Citroen 2 CV, in pigeon blue. And I was not the only one: The number of cars on the road has been increasing drastically over the last years (Fig. 1).

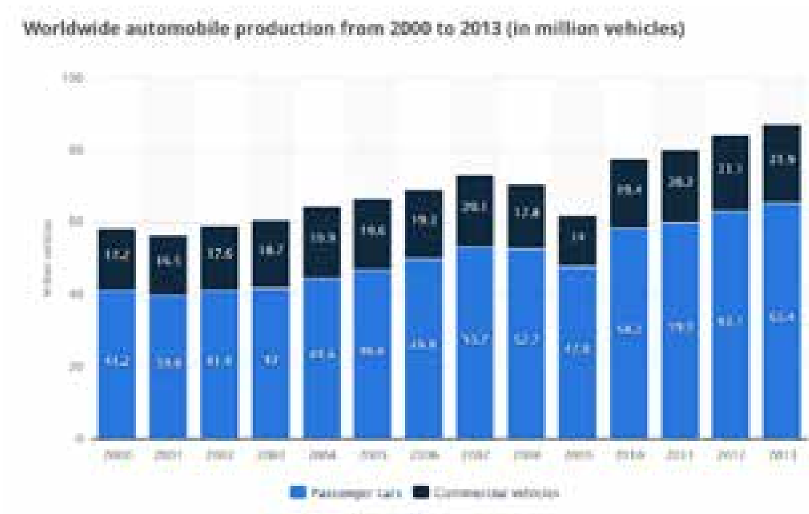

Fig. 1: Worldwide production of cars [1] Statista, Inc., http://www.statista.com/statistics/262747/worldwide-automobile-production-since-2000/

And with the increase of cars running worldwide on the roads, the emission of CO_2 is increasing as well. Fig. 2 shows the increase of CO_2-emissions over the last 40 years in the transport sector where cars have by far the biggest share (Fig. 2). It has been established as a scientific fact by the Intergovernmental Panel on Climate Change (IPCC) during the last 26 years that CO_2 is the major anthropogenic Green House Gas (GHG) accounting for 76 % of all anthropogenic GHG-emissions.

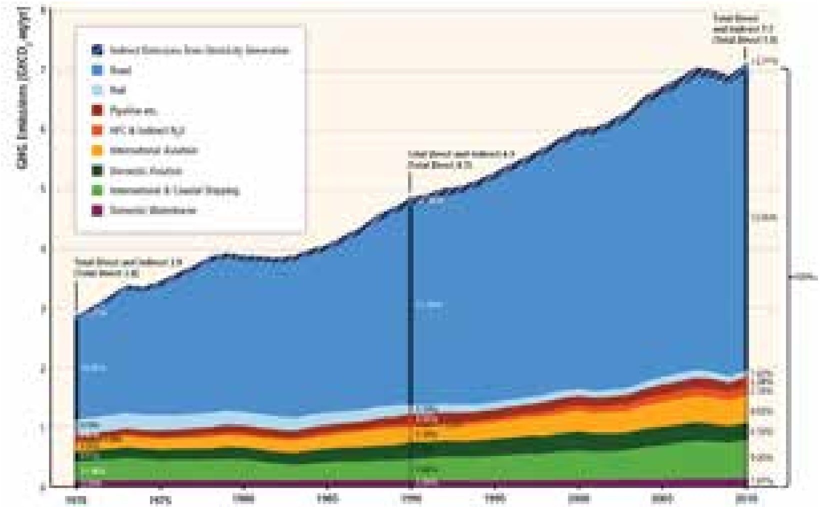

Fig. 2: CO_2-Emissions from 1970 to 2010 [2]

Direct GHG (Grean House Gas) emissions (shown here by transport mode) rose 250 % from 2.8 Gt CO_2 eq worldwide in 1970 to 7.0 Gt CO_2eq in 2010 (indirect emissions from production of fuels, vehicle manufacturing, infrastructure construction etc. are not included).

As a consequence of this, it has been agreed in the EU that CO_2-emissions have to be decreased until 2020 significantly. One way to achieve this is the EU legislation that limits the amount of emitted CO_2 / km in three steps until 2020 (Fig. 3).

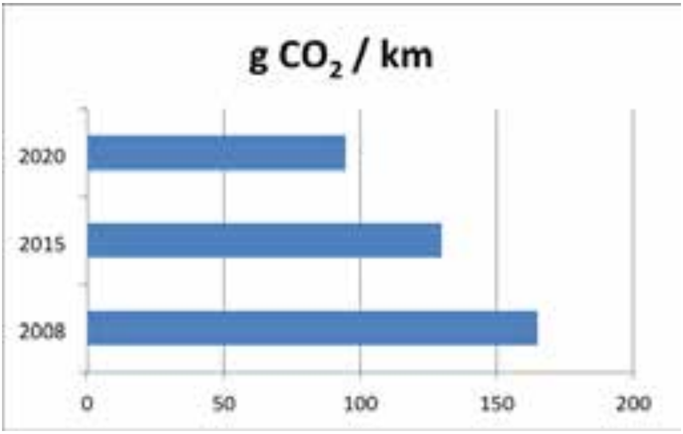

Fig. 3: EU legislation: tolerable CO_2-emission of a car [3]

There are further legislations worldwide, e.g. Singapore started in 2012 with a reduction of the tolerable CO_2 emission of 160 g / km. And the US made a proposal to allow only cars on the road in 2025 which need at most 4.3 l / 100 km [3].

HOW DO THE CAR PRODUCERS DEAL WITH THIS CHALLENGE?

E.g. Daimler has shown in his sustainability report in 2011 that the Mercedes Benz passenger car fleet in Europe has already achieved a clear reduction in CO_2 emission (Fig. 4). Their fleet released in average 230 g/ km in 1995. This amount had been reduced to 150 g / km in 2011, a reduction of ca. 35 %.

However these numbers will not meet the goals set for 2015 or 2020.

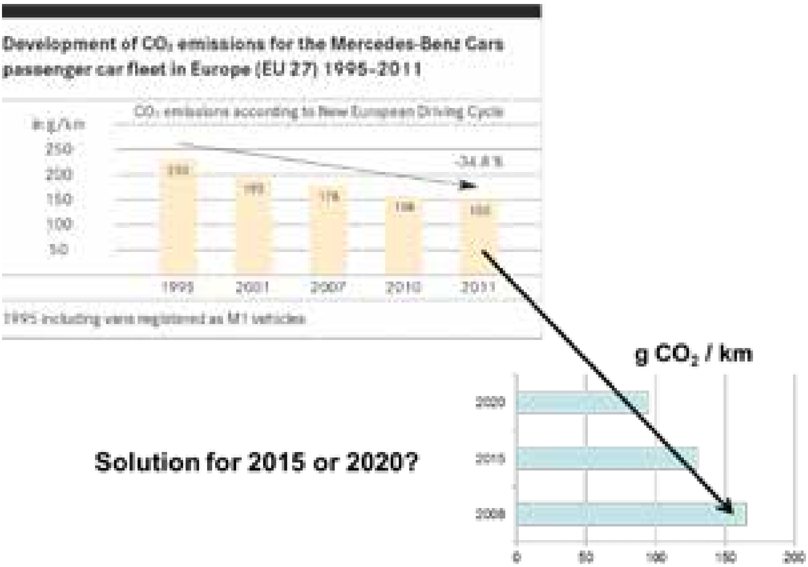

Fig. 4: Development of CO_2-emissions for the Mercedes Benz Cars passenger car fleet in Europe (EU 27) from 1995 to 2011 [4]

HOW TO SOLVE IT?

The reduction of the CO_2-emission can only be accomplished by a reduction of the fuel consumption of cars. There are different possibilities to do this and in the end all of them have to be exploited. One possible solution to fit the CO_2 legal requirements can be a lightweight construction. The following thought experiment shows this:

A reduction of 100 kg of a car leads to a fuel reduction of 0.35 - 0.5 l / 100 km. Or in other words, a reduction of 100 kg of a car leads a reduction of 8.8 to 12.5 g CO_2 / km.

In the past there has been a clearly different trend: the cars became heavier and heavier (Fig. 5). In the last 40 years, the vehicle weight for compact cars in Europe has nearly doubled. It is a very recent development that this trend appears to be slowing down.

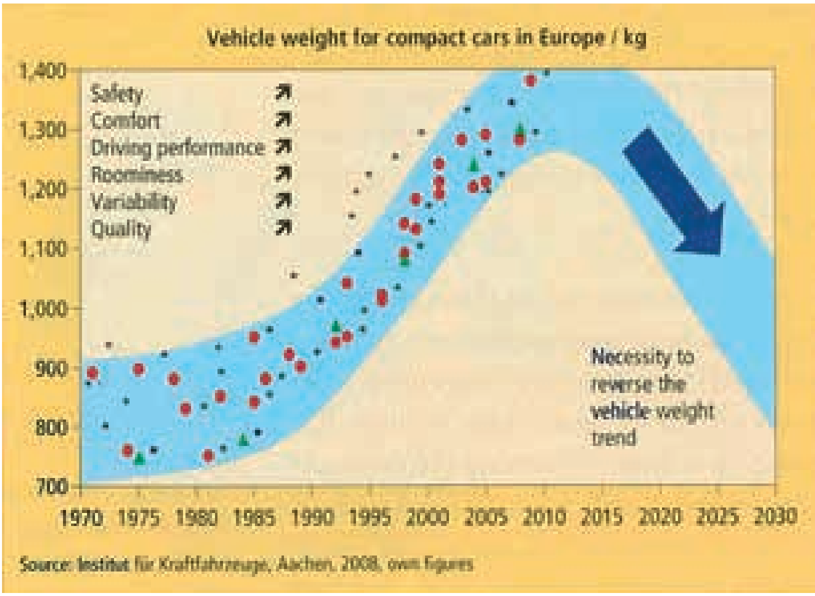

Fig. 5: Vehicle weight development for compact cars in Europe from 1970 to 2010

The weight development of a Mini Cooper is an example for this. It gained 420 kg weight in 47 years which means based on weight alone an increase in CO_2 of 37-52.5 g CO_2 / km (Fig. 6).

Fig. 6: Weight Development in Mini Coopers [3]

The same is true for the different Golf Series (Fig. 7 and Table 1). The weight of the Golf 1, launched in 1974, was lower than 800 kg whereas the vehicle weight of a Golf 6, launched in 2008, was more than 1200 kg. A first tendency to lower weight can be seen in the new Golf 7: it lost nearly 100 kg of weight.

Another clear tendency which can be seen by following the development of the different Golf series is the increasing amount of plastics which are used inside the car. In 1974, only 93 kg of plastics were used in the Golf 1, whereas 250 kg plastics were integrated in the Golf 6. The 15-20 wt.% plastics in the car corresponds to 8-10 % of the whole plastic market.

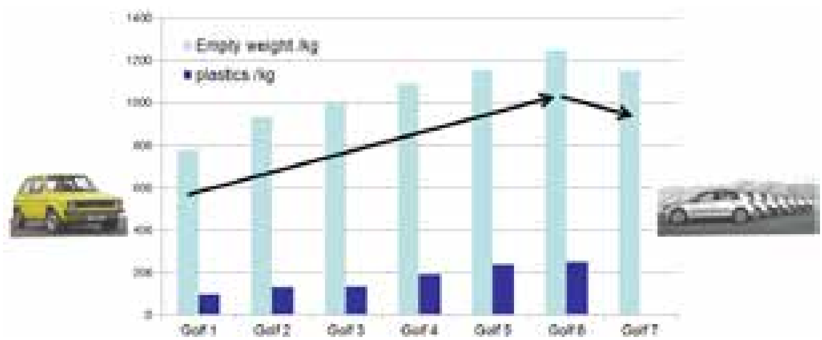

Fig. 7: Weight Development in the Golf Series [5]

Table 1: Weight Development in the Golf Series [5]

	Golf 1	Golf 2	Golf 3	Golf 4	Golf 5	Golf 6	Golf 7
Launched in	1974	1983	1991	1997	2003	2008	2012
Empty Weight /kg	775	930	1005	1090	1154	1250	1150
Plastics /kg	93	129	124	190	225	250	
Plastics /% of Total Empty Weight	11.7	14	12	18	18	20	
Consumption l/100 km			3.0	3.0	3.4	4.5	3.8

WHAT ARE THE REASONS FOR THE INCREASE OF WEIGHT?

On the one hand, there are increasing customer demands like radio, navigation, electric window regulators, air conditioning and seat heating. On the other hand, there are increasing safety demands like airbags and a stiffer construction.

How has the Golf 7 lost weight compared to Golf 4?

It lost 3 kg electrics, 22 kg of aggregates, 26 kg of chassis and 37 kg of construction. Volkswagen used ultra-stiff hot-formed steal to decrease the weight of the chassis. Reduction of 37 kg in the construction was achieved with the following measures [6]:

- **0.4 kg = Dashboard**: 20 % lighter dashboard thanks to a new thermoplastic foam
- **1.4 kg = Module cross-member (beneath dashboard):** lightweight construction concept using steel components and employing finite element method (FEM) analysis to optimize steel wall thicknesses
- **2.7 kg = Air conditionin**g: optimized thickness of various system components walls, reduced diameters of pressure lines, a new fastening system and a weight-optimized high-performance heat exchanger
- **7.0 kg = Front and rear seats**: The use of finite element method (FEM) and high-strength steels combined with laser welding enabled optimized wall thicknesses and profile geometries
- **23.0 kg = Body**: utilization of high-strength steel
- **2.5 kg = Miscellaneous**

An obvious possibility to reduce weight is to use thermoplasts and elastomers instead of steal in cars. A clear tendency for this is visible in a A.T. Kearney analysis (Fig. 8). The contribution of rubber has increased from 2 % in 1970 to 6 % in 2010, that of plastics from 6 % in 1970 to 16 % in 2010.

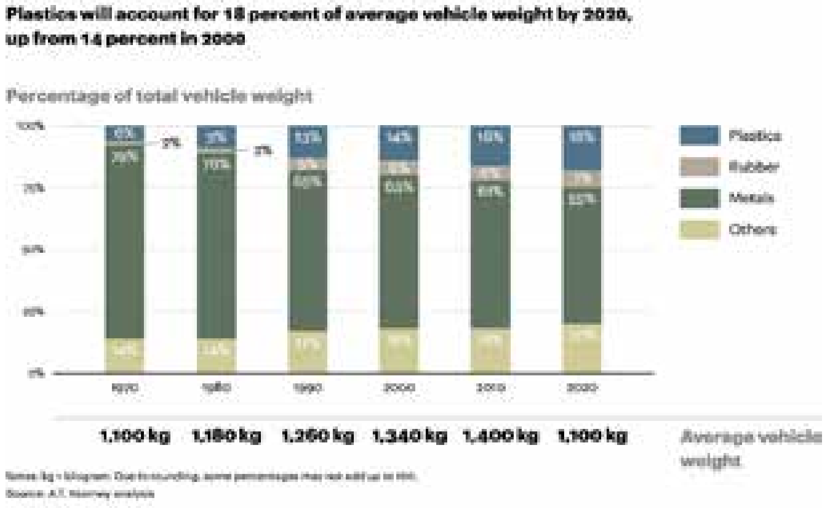

Fig. 8: Contribution of rubber, plastics, metals and other to the total vehicle weight

WHERE ARE THERMOPLASTS ALREADY USED IN CARS?

Thermoplasts are used e.g. in bumpers, sidings, heater, electrical installation, cooling systems and in interior equipment (Fig. 9 and 10).

Fig. 9: Thermoplasts in cars [7]

Fig.: 10: Thermoplasts in the interior of a car [7]

AND WHERE ARE ELASTOMERS USED IN THE CAR?

Elastomers can be used in tires, vibration mounts, brakes, bushings and mounts, headlight boots, cooling system hoses, engine gaskets and engine transmission mounts and seals (Fig. 11). Furthermore, also TPE ((Thermoplastic elastomers) and Duroplasts are used in cars.

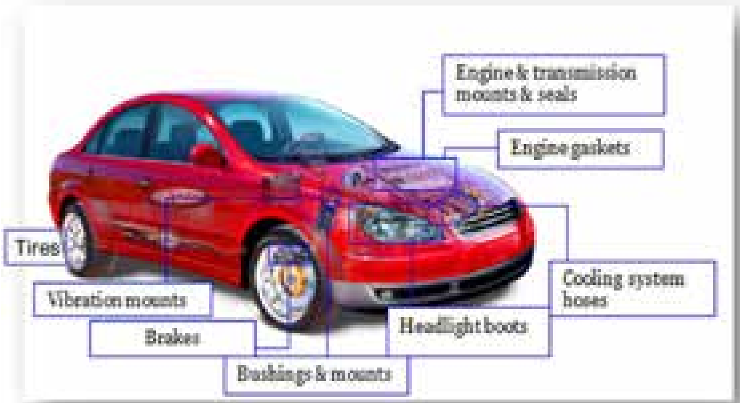

Fig. 11: Elastomers inside the car [7]

BUT WHAT ARE THESE DIFFERENT MATERIALS?

- Thermoplasts: thermosoftening plastic, a polymer that becomes moldable above a specific temperature and returns to a solid state upon cooling (Acrylic (poly(methyl methacrylate) (PMMA)), Nylon, Polyethylene (PE), Polypropylene (PP), Polystyrene, Polyvinyl chloride (PVC), Teflon)
- Elastomers: polymer with viscoelasticity (Natural Rubber (NR), Styrene-Butadiene Rubber (SBR), Butadiene Rubber (BR), …..)
- TPE (Thermoplastic Elastomers): copolymers or a physical mix of polymers (usually a plastic and a rubber) which consist of materials with both thermoplastic and elastomeric properties (Styrenic block copolymers (TPE-s), Polyolefin blends (TPE-o), Elastomeric alloys (TPE-v or TPV), Thermoplastic polyurethanes (TPU), Thermoplastic copolyester, Thermoplastic polyamides)

- Duroplasts: composite thermosetting plastic, fiber-reinforced plastic (fibers either cotton or wool, similar to fiberglass (“Trabant!”))

By comparing the amounts of all four materials in a BMW 3 series having an empty weight of 1403 kg with a BMW 7 series having an empty weight of 1899 kg it becomes obvious that e.g. the amount of elastomers was increased from 62 kg (= 4.4 % of the total weight) to 69 kg (= 3.6 % of the total weight), that of thermoplasts from 161 kg (= 11.5 % of the total weight) to 236 kg (= 12.4 % of the total weight) (Fig. 12). Also 34 or 46 kg respectively Duroplasts are inside the BMW – the “Trabi” material!

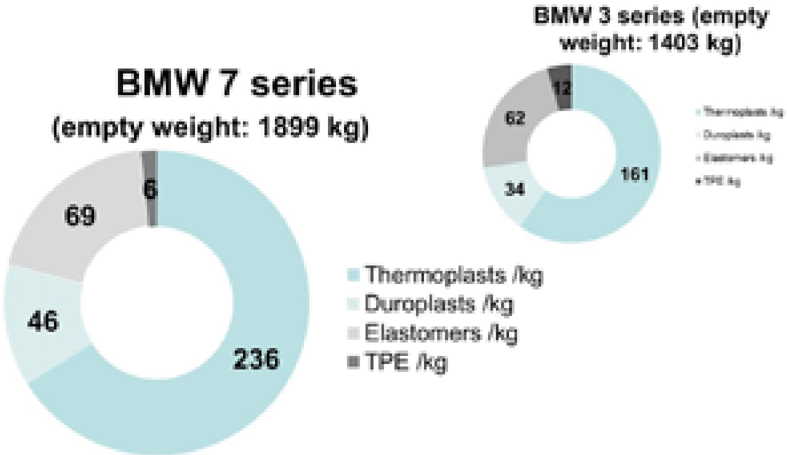

Fig. 12: Thermoplasts and Elastomers in a BMW 3 Series versus 7 Series [3]

WHAT ARE THE CRITERIA FOR THE USAGE OF THERMOPLASTS IN CARS?

Advantages:

- light weight
- chemically resistant
- can easily be shaped
- durable
- easy to color in the mass
- thermally insulating
- acoustically insulating
- electrically insulating
- energy saving
- cheap
- good damping properties

Disadvantages:

- indestructible, harmful gas is evolved by melting which weakens the ozone layer
- most plastic is produced from mineral oil which is not available for ever (alternatives: e.g. vegetable oil as source)
- threat of compound braking at high temperature and long-term stress
- inflammable
- difficult to paint

In 2009, the front side wall of BMW 3 series Coupé / cabriolet were introduced. It was made from mineral reinforced PA 66 (polyamide) and acrylnitrile / polybutadiene / styrene. The weight reduction compared to steel was 3 kg which delivers also a small contribution to CO_2-reduction. The innovation here was that the length expansion was compensated with a special fixing system which made an online-painting together with steel components possible.

EU TIRE LABELLING

Another important possibility to reduce the CO_2-emissions of cars is the use of low rolling resistance tires that lower the fuel consumption. The European government increased the pressure on the tire industry to develop such tires by implementing a tire label in November 2012 (Fig.13). It defines seven classes from G (least efficient) to A (most efficient). Compared to a G-labelled set of tires an A-labelled one can reduce fuel consumption by up to 7.5 % and even more in case of trucks.

Fig. 13: Tire Label introduced by the European Commission (left) and fuel savings between the different grades (based on a vehicle with an average fuel consumption of 6.6 l) (right) [8]

Goodyear Innovation Centre calculated the reduction of fuel consumption in 2012 by using an A-labelled tire instead of a F-labelled tire on a 40 ton five-axle articulated truck (Fig. 14):

Average fuel consumption of vehicle 32,3 l/100km → 323 l/1000 km → 14.7 % potential savings = 47.5 l less fuel consumption per 1000 km → fuel price 1.50 EUR/litre = 71.25 EUR/1000 km → 100,000 km mileage/year = 7125 EUR savings/year.

Fig. 14: A- versus F-labelled tire for a 40 ton five-axle articulated truck [9]

This means a fleet owner can reduce the fuel consumption of one truck by up to 15 % which results in savings of around 7125 euros per year. Of course CO_2-emissions are lowered as well.

TRENDS IN THE AUTOMOTIVE INDUSTRY

As seen before, there is a trend in the automotive industry to an increasing use of lighter elastomers and thermoplasts in cars for weight reduction resulting in a reduction of fuel and therefore of CO_2-emissions. Unfortunately the production of elastomers and thermoplasts is based mainly on petrochemical products. Therefore, an increased use of elastomers and thermoplasts also leads to an increased use of crude oil (Fig.15).

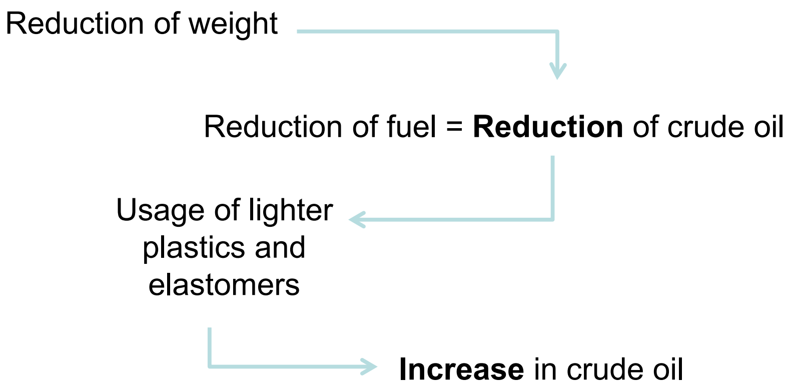

Fig.15: Consequences of using thermoplasts and elastomers as construction material for cars with the aim to reduce fuel consumption.

How can this problem be solved which will become more and more pressing as it can be expected that crude oil prices will rise as they have done in the past 25 years (Fig.16).

Fig.16: Crude Oil Price Expectation [10]

One solution can be natural rubber, the only bio-polymer of commercial interest. Natural rubber is harvested mainly in the form of latex from special trees. The major commercial source of natural rubber latex is the Pará rubber tree (Hevea brasiliensis) (Fig.17). Latex is a sticky, milky colloid harvested by making incisions into the bark and collecting the fluid in vessels in a process called “tapping”. The latex then is refined into rubber ready for commercial processing. Natural rubber is used extensively in many applications and products, either alone or in combination with other materials. The advantages of this rubber are the large stretch ratio, a high resilience and an extremely waterproof [11].

Fig.17: Latex being collected from a tapped rubber tree, Cameroon (left) and a woman in Sri Lanka in the process of harvesting rubber (right) [12]

There are other very important aspects regarding the availability of natural rubber: rubber trees sprout exclusive in tropical zones like Thailand, Indonesia, Malaysia or Vietnam. They are harvested in monocultures which means that all rubber trees are genetically very similar. And, as always in monocultures, there is the big threat of diseases which can destroy a whole plantation. *Hevea brasiliensis* is vulnerable to several pests. The Asian owners of rubber plantations are especially worried about the spread of the fungus „South American Leaf Blight (SALB)" which has already destroyed many South American plantations.

Due to Asia being the main source for latex, there is a clear threat of big price differences. For example from 2007 to 2012 the price for natural rubber fluctuated between 0.80 € / kg and 3 € / kg on the Malaysian market (Fig.18). Therefore, the rubber industry is searching for alternative bio-based sources for rubber latex. Two interesting alternatives have already been identified: Mexican guayule and Russian dandelion.

Fig.18: Price movements for natural rubber (1 Euro = 3.91 Malaysia Ringgit (RM)) [13]

Guayule is a Mexican shrub (Parthenium argentatum Gray) (Fig.19). It sprouts independent from specific climate conditions and is robust and undemanding. Furthermore, a yearly harvest is possible. Another advantage is that guayule does not cause allergic reactions like *Hevea brasiliensis*.

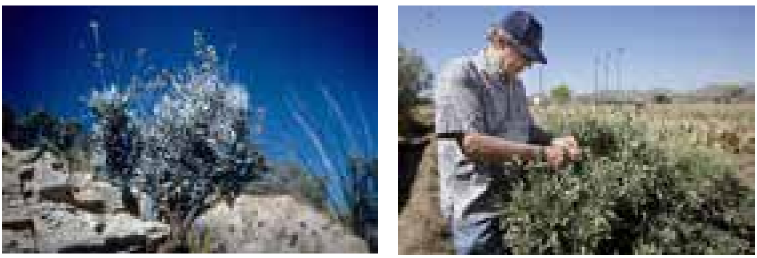

Fig.19: Guayule shrub (left) and University of Arizona professor Dennis Ray with guayule bushes at the UA agriculture center (right) [14]

The industry has already started to invest in guayule research, especially in the US with the objective to be independent from the Asian rubber monopoly. Continental Mexican Rubber Co., which was founded in the first decade of the 20th century, exported about 42,000 tons of rubber extracted from wild plants to the U.S. from Mexico in 2013 [15].

Bridgestone announced in March 2012 that they had established a pilot farm and were constructing a rubber process research center in the Southwestern United States to focus on the development of Guayule plant rubber. Yulex Corp., which was founded in 1997, is a member of the Biomass Research and Development Initiative. The tire company Cooper, the Agriculture Resource Service and the Arizona State University (created 2012 via a $6.9 million grant) are members of Yulex. The US awarded a $3 million, five-year grant to Phoenix-based Yulex Corp. focused on developing guayule rubber ready for start of production. They want to have the first guayule rubber samples available for evaluation as a component in tires by mid-2015 which is a very ambitious goal!

The other alternative is Russian dandelion (Taraxacum koksaghyz). Thinking of dandelion which is present nearly everywhere (especially in gardens where the owners could do without it) it becomes clear that it sprouts independent on specific climate conditions, is robust and undemanding, even in comparison to guayule. Russian dandelion is specially cultivated with very long roots (Fig.20, left). These long and thick roots have the right mix of rubber polymers, proteins and fatty acids like natural latex. But in contrast to Hevea brasiliensis, the latex from Russian dandelion does not cause allergic reactions.

The Russians first discovered the potential for harvesting rubber from dandelions in the 1920s. When natural rubber was in limited supply during World War II due to demand for airplane and truck tires, the U.S. also began exploring the dandelions as an alternative source. However this research was abandoned after the war. Nowadays, the interest in Russian dandelion is growing again.

The Ohio Agricultural Research and Development Center in Wooster / Bridgestone Corp. / Ford Motor Co. wants to harvest natural rubber from Russian dandelion. Bridgestone announced in May 2012 “promising results indicating that the Russian dandelion can become a commercially viable, renewable source of high-quality, tire-grade rubber”. Another example is the co-operation between the Fraunhofer Iinstitut IME (Aachener Institut für Molekularbiologie und angewandte Ökologie) and Continental. They started a project for breeding of Russian dandelion with higher latex content in a pilot plant in Münster, Germany (Fig.20, right). The goal is the replacement of 5-10 % of Hevea brasiliensis by Russian dandelion in the short term [16].

Fig.20: Russian dandelion (left) and Russian dandelion pilot plant in Münster / Germany (right) [17]

Apollo recently built prototypes of tires with natural rubber made from guayule and Russian dandelion (Fig. 21). They have just started an intensive testing phase before they want to move to the production phase. The goal is to create an alternative to Asia’s rubber monopoly and to launch a new generation of environmentally-friendly tires in Europe in the very near future [18].

These bio-based alternative sources for natural rubber have a huge potential for the future, especially as crude oil will become scarce in the long term! Their use in different parts cars will also help to reduce the consumption of fuels made from crude oil and to reduce as a consequence the CO_2-emissions.

Fig. 21: Apollo's prototype of a tire with natural rubber made from guayule and Russian dandelion [19]

SUMMARY

Car traffic has a significant share in worldwide greenhouse gas emissions. Despite many improvements in the past there is still a big potential for further reductions ofthe CO_2-emission. Many parts of a car can be replaced by thermoplasts or elastomers in order to reduce weight. In addition all tire producers are working on solutions to decrease the CO_2-emissions, e.g. by reducing the rolling resistance (Fig. 21). One important aspect in both areas – at least in the long term - will be the use of bio-based products.

Therefore, the answer to the question "Can rubber help against the greenhouse effect?" is "yes – as one piece of a huge puzzle".

Fig. 22: CO_2-reduction as a common goal for all tire producers [20-25]

LITERATURE

[1] Statista, Inc., http://www.statista.com/statistics/262747/worldwide-automobile-production-since-2000/

[2] Intergovernmental Panel on Climate Change (IPCC): Climate Change 2014: Mitigation of Climate Change, http://www.ipcc.ch/report/ar5/wg3/

[3] Kunststoffe im Auto – was geht noch?“, GAK 4/2013 Jg. 66, p. 248-258

[4] Daimler Sustainability Report 2011

[5] Spritmonitor.de, http://www.spritmonitor.de/de/uebersicht/50-Volkswagen/452-Golf.html

[6] Plastics today, http://www.plasticstoday.com/blogs/vw-sticks-steel-golf-car-weight-slashed-100-kg-plastic-composite-20120913a

[7] D. Kyriacos: Polymers in Cars, GEM-CHEM

[8] European Commission; Continental: EU tire label, April 2011

[9] TIP Trailer Services, http://www.tip.ge.com/about-us/news/welcome-eu-tire-label

[10] L. David Roper: World Fossil-Fuels Depletion, http://www.roperld.com/science/minerals/fossilfuels.htm

[11] Heinz-Hermann Greve “Rubber, 2. Natural”, in Ullmann’s Encyclopedia of Industrial Chemistry, 2000, Wiley-VCH, Weinheim

[12] Wikipedia: natural rubber, http://en.wikipedia.org/wiki/Natural_rubber#Biosynthesis

[13] KiasuTrader: Rubber Gloves - Mid-Term Outlook Still Bright, http://journeytowealth88.blogspot.de/2012/11/rubber-gloves-mid-term-outlook-still.html

[14] Rubber & Plastics News, Guayule, TKS show promise as rubber source, http://www.rubbernews.com/article/20130603/ISSUE/306039989/guayule-tks-show-promise-as-rubber-source

[15] rubber news.com, June 7, 2013; http://www.rubbernews.com/article/20130603/ISSUE/306039972#

[16] Hannoversche Allgemeine Zeitung (HAZ), October 17, 2013

[17] Sarah Jane Tribble: Researchers in Ohio working to see if dandelions can be future of the tire industry; http://blog.cleveland.com/metro/2012/09/from_weeds_to_riches_the_makin.html

[18] Job K.A.: Trends in green tire manufacturing, Rubber World Vol. 249, No. 6, March (2014) 32-38
[19] Gizmag: Europeans turn to guayule and Russian dandelion as sources of latex, http://www.gizmag.com/russian-dandelion-guayule-latex/23362/pictures
[20] Apollo Vredestein B.V.: Environmental report 2010 http://www.apollovredestein.nl/sitefiles/MILIEUJAARVERSLAG-2010%20ENG.pdf
[21] UNITED NEWS NETWORK GmbH: Renaults CO_2-freie Elektro-Limousine Fluence Z.E. steht auf EfficientGrip von Goodyear, http://www.pressebox.de/pressemitteilung/goodyear-dunlop-tires-germany-gmbh-hanau/Renaults-CO_2-freie-Elektro-Limousine-Fluence-ZE-steht-auf-EfficientGrip-von-Goodyear/boxid/311301
[22] Bridgestone Corporation: Reducing CO_2 emissions throughout our product lifecycles, http://www.bridgestone.com/responsibilities/environment/mission/emissions.html
[23] Michelin Reifenwerke: Challenge Green, http://www.michelin.de/unternehmen/challenge-green
[24] Continental AG, " Neue Continental-Studie: Klimadiskussion lässt Interesse an Kauf von Hybridfahrzeug deutlich steigen"; http://www.continental-corporation.com/www/csr_com_de/themen/news/hidden/archiv/archiv_umwelt/conti_studie_hybridfahrzeuge_de.html
[25] Pirelli & C. S.p.A.: Annual financial report 2008, http://www.pirelli.com/investor/2008/ENG/online-report/html/pages/29/index.html

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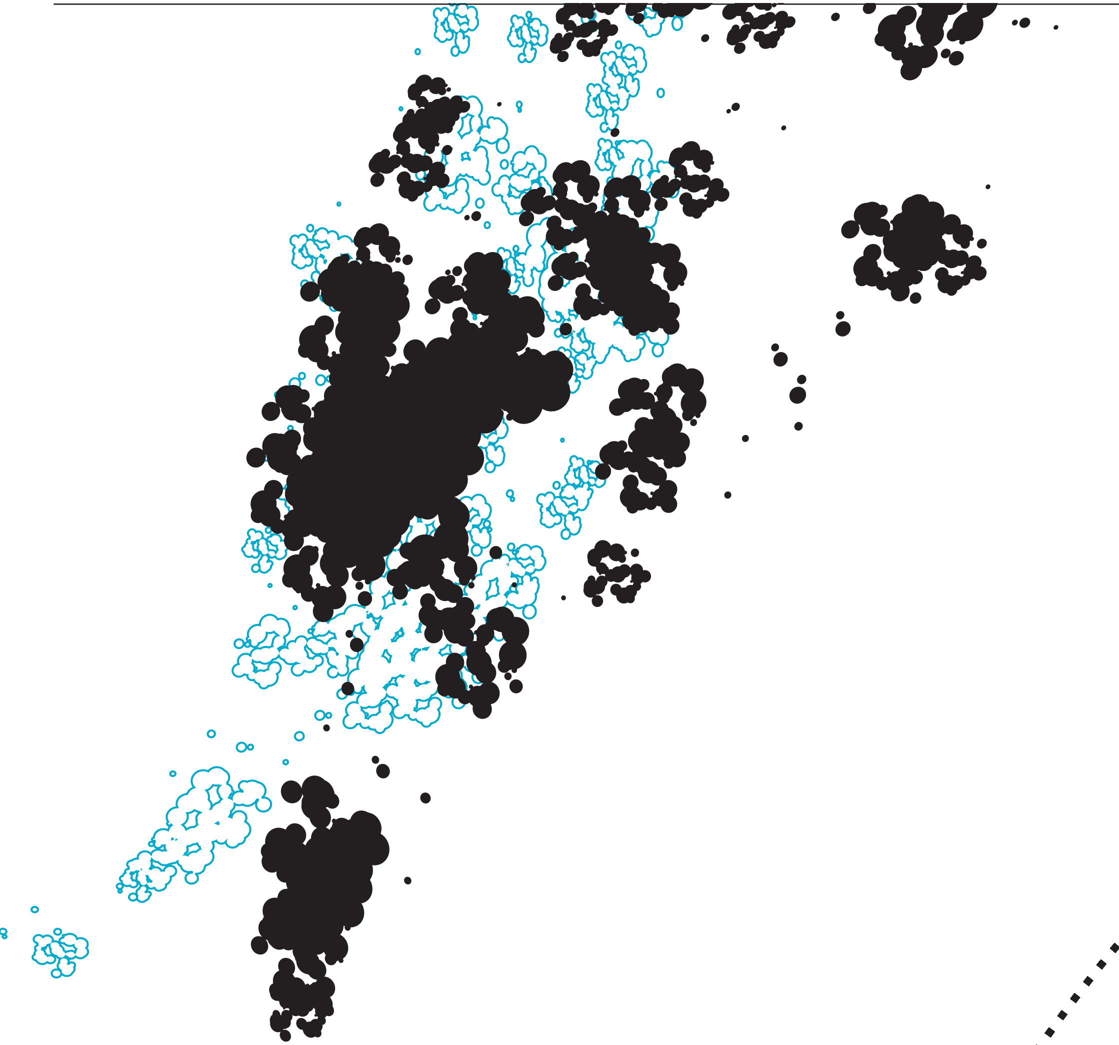

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