# what matters 2015

Nitrogen: Too much of a good thing? > Waste not, want not > Mobility of the future

Annual Report of the German Environment Agency

## Umwelt 🎲 Bundesamt

For our Environment

#### WHAT MATTERS 2015

## **Electromobility is the only** way to truly improve the air in our cities

Maria Krautzberger President of the German Environment Agency

When Carl Benz invented the automobile, it would have been almost impossible to predict the influence his "self-moving vehicle" would have on the world. Today, nearly 130 years later on, the car has had a greater impact on our lives than almost any other invention. It shapes our cities and connects our rural regions. Many of us also have vivid memories of automobiles: holiday trips as kids, our very first car, perhaps even our first kiss on the back seat. For a long time, however, we have also felt the negative consequences of private transport. Valleys of idyllic meadows are often cut up by snaking, four-lane stretches of asphalt. Noise and dirty air impair our quality of life, particularly in cities. And when endless traffic jams line our highways and fill our towns, "going for a drive" seems more like "sitting in the car".

All of this costs time and money. It also puts a great strain on the environment. The transport industry is responsible for nearly a fifth of Germany's greenhouse gas emissions. And in contrast to the energy sector, for example, this situation has not changed in the last 25 years – in terms of volume, transport emissions have remained unvaryingly high, and have even seen slight increases. If we want to reduce our  $CO_2$  emissions, something has got to change. There are plenty of approaches to tackling this problem. We could plan our cities differently, allowing us to get places more easily without burning any gasoline. We could take the bus and train more often. Or we could convert our cars to use motors that do not consume any fossil fuels at all - electromobility would be one option here. The latter is far from a new idea: back in 1900, in the early days of the automobile, 28 percent of the vehicles in the USA were powered by electricity. This number decreased rapidly as people increasingly wanted to drive further and more quickly, something that was not possible with the electrical technology of the age. It is possible today, however. There is still room for improvement, but e-mobility would be perfectly sufficient for the majority of journeys made in Germany every day.

An e-car has two crucial advantages over a conventional motor. First of all, it emits no  $CO_2$  while driving. Admittedly, this is not also currently the case with the electricity that powers the car. To have a truly  $CO_2$ -neutral automobile, we also need  $CO_2$ -neutral electricity.

Only when 100 percent of our electricity comes from the sun, wind and water will we also be able to significantly reduce the greenhouse gas



emissions from the transport sector. Nevertheless, e-cars already have a second advantage up their sleeves today: no fumes come out of their exhaust pipes. This is important, as our air – especially that in many cities – is heavily polluted with particulate matter and nitrogen dioxide. Both substances can harm our health. The EU has laid down pollution limits as a result, but nitrogen dioxide restrictions are not being complied with at over 60 percent of our urban measuring stations.

We need to talk about nitrogen. This element is an essential building block of life. The air we breathe is largely made up of it (78 percent), we humans consist of it to a certain extent, and plants grow better when they have more of it at their disposal. Nitrogen can also cause problems, however. We now use so much fertiliser that our rivers, lakes and - in many places – our groundwater are contaminated with nitrate. This leads to massive changes in our ecosystems. Biodiversity suffers and bodies of water become barren as the presence of too much nitrogen leads to the excessive growth of algae, which "suffocates" all other life in the water in turn. This has already led to veritable "dead zones" in the Baltic Sea where no other life can now be found. For this reason, the agricultural industry urgently needs to find ways to bring less nitrogen into circulation. Our chapter on nitrogen in this publication puts forward the suggestions made by the German Environment Agency on this issue.

This year's third key issue is the use of waste as a resource. Here, too, we find points of intersection with mobility: cars and – above all – e-mobiles are full of electronics, after all. Such devices require numerous precious and special metals like gold or neodymium. These are only available in limited quantities on earth, however. A literal treasure trove of such materials is concealed in old gadgets like mobile phones and electric toothbrushes, and could be extracted via an improved recycling system. Perhaps this could lower the cost of electromobility and quickly bring it back to levels seen in the early twentieth century. Our environment and our health would thank us for it. WHAT MATTERS 2015

## **Contents**

## 6 What next for Kyoto? – International climate politics ahead of the Paris Conference





20 Nitrogen. Too much of a good thing? Useful or harmful? A substance with many facets



**38** Waste not, want not How the modern circular economy works



**62 Mobility of the future** The (energy) transition in the transport sector

ABOUT THE GERMAN ENVIRONMENT AGENCY

82 Protecting drinking and swimming water 92 Editorial information / Photo credits



## What next for Kyoto? – a look at the international climate politics of the last two decades

The United Nations Framework Convention on Climate Change was adopted more than 20 years ago. Regarded as a milestone in international climate protection, it came into force in 1994 and has more than 196 signatory parties today. In 1997, industrialised nations made a legally binding commitment to reduce their greenhouse gas emissions for the very first time under the Kyoto Protocol – a significant step towards combating climate change. And with the enactment of the Paris Agreement, all states are now finally bound by concrete obligations.

## The Kyoto Protocol's first commitment period: an assessment

The steady rise in global greenhouse gas emissions raises a question: the Kyoto Protocol came into force in 2005, and its first commitment period ended in 2012, but how successful has it actually been? It is true that – aside from a handful of individual market-related slow-downs – global greenhouse gas emissions have nearly doubled since the 1970s. Around 28 billion tonnes of greenhouse gases were emitted globally in 1970. This figure had already risen to 38 billion tonnes by 1990. In the following two decades, emissions increased to a current record level of approx. 53 billion tonnes of CO<sub>2</sub> equivalent per year.

A more nuanced picture reveals itself upon closer examination, however. Up to the early 1990s, a clear dichotomy could be seen between the high greenhouse gas emission levels of industrialised nations (Annex I of the UNFCCC) and the low levels of developing countries (Non-Annex I). Since the international climate protection regime came into force, however, there have been significant shifts: although emissions from large developing economies have increased considerably, many Annex I states have stabilised or even reduced their own levels.

Another distinction is important here. The entire greenhouse gas emissions of all Annex

I states rose to around 17 billion tonnes by 2012, a 13 percent increase in comparison to 1990 levels. Examining the development of those industrialised nations that made a reduction commitment under the Kyoto Protocol tells a different story, however: their emissions dropped by 22.6 percent below 1990 levels. Until the mid 1990s, this was primarily due to the industrial collapse in Central and Eastern Europe and the former Soviet Union. From around the year 2000, however, the other industrialised nations also began to record significant emission reductions.

If this is compared with the overall numerical goal of the 1st commitment period – a reduction of 5.2 percent – the Kyoto Protocol can certainly be viewed as a success, at least with regard to the states that took part. However, due in part to geographical shifts in emission activities, the Kyoto Protocol now only covers around 15 percent of the emissions produced in the world today.

#### Greenhouse gas emissions in the EU

The European Union (EU) is one of the biggest emitters in the world. Within the EU itself, Germany is the largest emitter, followed by Great Britain, France and Italy. These four states combined give rise to more than half of

the greenhouse gas emissions in today's EU of 28 Member States (EU-28). Back in 1997, the EU – which was then composed of 15 Member States (EU-15) - made a commitment under the Kyoto Protocol to reduce its emissions in the 1st commitment period by 8 percent in comparison to the base year. This commitment was fulfilled due to an internal EU effort sharing agreement to distribute the load between the individual Member States.

A distinction must certainly also be made today between the EU of 28 Member States and the (former) EU-15: the level of greenhouse gas emissions decreased by 19.2 percent overall in the EU-28 by 2012, but only by 15.1 percent in the EU-15. This reduction can be attributed to a greater degree of efficiency in energy conversion, to more climate-friendly methods of energy production, and to the consequences of economic transformation.

The EU Member States have developed very differently since 1990. While a few of the Member States (particularly Germany, Great Britain and the Eastern European countries - the latter due in part to the economic upheavals at the beginning of the 1990s) were already able to bring about large emission reductions before the economic and financial crisis took place, other Member States have only achieved modest decreases.

A development comparable to the overall global trend can thus be observed in the EU: while emissions have recently increased in the Eastern European Member States (in a similar fashion to other developing countries), the reverse



is partly true of the EU-15 (Annex I) states. The bulk of the reductions took place in the latter after the year 2000.

#### What about Germany?

Germany emitted 1.256 million tonnes of greenhouse gases in 1990. By 2012, it was able to reduce its emissions by 23.8 percent compared to 1990 levels and - as had already been the case in 2009 and 2010 - was able to fulfil its agreed reduction commitment (a decrease of 21 percent compared to 1990).

The sharp drop in emissions seen in the early 1990s can predominantly be attributed to the reorganisation of the new German states (Länder) and the corresponding switch to lower-emission sources of energy (i.e. from coal to liquid and gaseous fuels), the decommissioning of ageing plants and the reduction of the livestock population in the agricultural sector. Furthermore, putting an end to depositing untreated waste as landfill from 1st June 2005 led to a significant decline in harmful emissions from the waste management industry. Over the last few years, the predominant factor in reducing emissions has been the increased use of renewable sources of energy.

paint a heterogeneous picture overall: after a rapid 6.9 percent reduction in 2009 caused by the international economic and financial crisis, levels increased again by 3.8 percent in 2010 due to the economic recovery. Emissions then fell by 2.1 percent in 2011 – largely due to weather conditions - before rising once more in 2012 (0.6 percent) and 2013 (2.4 percent). 2014 was the first time in two years that emissions had fallen: a reduction of 4.3 percent in comparison to 2013, to be exact. This comes from a short-term forecast released by the German Environment Agency (UBA) in March 2015. In total, 912 million tonnes of greenhouse gas emissions were produced in 2014 - the lowest level since 2010. This corresponds to a reduction of 27 percent in comparison to 1990.

• Responsible for this text: Dirk Günther (Section I 2.6)

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The greenhouse gas emissions of recent years

#### The State of the Nations: what has been achieved?

#### Germany can become greenhouse gas-neutral

In order to avert the risks of climate change, the trend in greenhouse gas emissions must be completely reversed. For this to happen, a radical technological, economic and institutional transformation must take place. A study from the UBA, "Germany 2050 - a Greenhouse Gas-Neutral Country", explains how this can be achieved in highly industrialised nations. According to this report, it is possible to reduce the annual per capita emissions to just one tonne of CO<sub>2</sub> equivalent by 2050 – representing a 95 percent reduction in comparison to 1990 levels. The study is supported by criteria for developing the energy supply in a sustainable, environmentally friendly manner. The report shows that Germany can continue to be one of the world's leading industrialised nations in 2050 while implementing an entirely renewable energy supply and using it in an efficient way. The scenario selected in the study considered the conversion of the energy supply from a national perspective. Although interactions with other countries were not included in the report, the UBA would like to use it to enter into a debate with its international partner nations.

Climate protection is no longer perceived as a mere cost driver in the world today. Many countries now recognise the opportunities to be gained from this global challenge - not least because such nations as Germany have shown that climate protection and economic development can go hand in hand. This is an important sign, as the large developing and emerging nations have overtaken the industrial countries in terms of emissions. If we want to limit global climate change effectively, these states must also lower their greenhouse gas emissions in the future.

#### Climate policy development: assessing China, India and the USA

SSince 2006, China has replaced the USA as the world's largest emitter of greenhouse gases. In addition, India's greenhouse gas emissions have more than doubled since 1990. None of these three countries made any legally binding commitment to reduce their greenhouse gas emissions under the Kyoto Protocol. The USA never ratified the Kyoto Protocol and - as the Protocol's emission reduction measures were only directed at industrialised nations in their original form - China and India were not bound to any obligations from the outset.

It would be wrong to conclude that these countries have done nothing to protect the environment, however: climate protection is firmly embedded in their national politics. The topic has gained a growing significance in China's political system since the 1990s, for example. Back then, climate protection was still regarded as an economic and security-related issue. More attention is paid to the subject today, however, due to the nation's environmental and health concerns that are largely driven by the acute air and groundwater pollution caused by fossil fuels.

In the USA, climate protection underwent a renaissance as a relevant issue of state with the advent of the Obama presidency. A variety of measures were announced. Nevertheless, no comprehensive climate legislation has emerged to date. This may be due to the composition of the US Congress, among other factors. Despite this, it has been possible to use the Clean Air Act and even the Economic Stimulus Package to implement measures that contributed to reducing greenhouse gas emissions by twelve percent between 2005 and 2012. President Obama paved the way for further substantial emission reductions with the Climate Action Plan of 2013. The shale gas boom of recent years is also said to have made an important contribution to greenhouse gas reductions to date, as emission-intensive coal has been replaced in favour of gas, a lower-emission fuel. The effect of this is only seen on a national level, however. Although coal was supplanted by shale gas in the USA, the situation resulted in the exportation of low-cost coal to Europe, where it was converted into electricity and thus increased emissions (see UBA Texte 53/2014).

For a long time, climate protection did not feature in India's national legislation. Fighting poverty and stimulating economic development are the nation's highest priorities. As around 600 million citizens have no access to electricity, action was required to build and expand the

#### Figure 1:

Development of emission intensity of the economy with regard to gross domestic product (t  $CO_2e/USD$ ) since 1990 in China, India and the USA (indexed, last available year (2011) = 1)



country's energy supply. Nevertheless, India has also recognised that protecting the climate and providing energy for its population are not mutually exclusive goals: the 2008 National Action Plan on Climate Change was devoted to measures to support the development of the nation while also protecting the climate. This trend is further manifest in Indian politics. For example, Narendra Modi, the new Prime Minister, had already campaigned for climate protection as Chief Minister of the Indian state of Gujurat. Among other things, he set up a dedicated "climate protection" agency and promoted solar power.

In a joint announcement made in November 2014, China and the USA revealed the contributions they would make to GHG reduction as part of a new climate deal. China declared that the rise in its national CO<sub>2</sub> emissions should peak by 2030 at the latest, and that the proportion of renewable energy sources in its overall primary energy consumption should increase by around 20 percent by the same year. The USA announced its wish to reduce its greenhouse gas emissions by 26-28 percent by 2025 (compared with 2005 levels). Both nations also officially submitted these objectives under the UNFCCC as their contributions to the new climate protection agreement. Their efforts must be strengthened further, however, as these goals will not be sufficient to avoid increasing the average global temperature by more than two degrees Celsius.

#### Joint Implementation and the Clean Development Mechanism: emission reductions in developing and transition countries

The 1997 Kyoto Protocol permits industrialised states to achieve part of their agreed reduction targets beyond their borders by making investments in foreign countries. International emissions trading and two project-based "flexibility mechanisms" – Joint Implementation (JI) and the Clean Development Mechanism (CDM) - exist for this purpose. JI concerns the cooperation between industrialised nations while the CDM promotes climate protection projects in developing countries. This allows emission reductions to be achieved where they are the most cost-effective. These emission reductions must be quantified and carried out in addition to reductions that would normally otherwise occur (e.g. those previously set down in law). In addition, projects must be harmless to both the environment and developmental politics. Part of the proceeds from CDM projects goes to finance the Kyoto Protocol's Adaptation Fund.

#### **Climate protection projects in practice**

By 31 December 2014, 7,578 CDM projects had been registered worldwide and reductions of 1.51 billion tonnes of CO<sub>2</sub> equivalent had been verified. The total volume of investments since 2004 stands at over 412 billion US dollars, with the majority being made in the renewable ener-



gies sector. By 31 December 2014, the German Emissions Trading Authority (DEHSt) at the German Environment Agency had approved 452 climate protection projects, 394 of which were CDM projects. China, India and Brazil were the most prolific CDM host countries by a wide margin. However, the supply of Certified Emission Reductions now exceeds the extremely saturated demand – which predominantly came from EU emissions trading - many times over. This caused a decline in the price of Certified Emission Reductions. For some time now, only a small number of new projects have been developed as a result. The weak demand for Certified Emission Reductions also endangers the continuation of certain CDM and JI projects that substantially or exclusively depend on the revenue from such credits. Germany contributed €15 million to the World Bank's PAF (Pilot Auctioning Facility) to strengthen these

market-based mechanisms. The Facility aims to secure emission reductions over the long-term and deliver a model for the financial safeguarding of climate protection projects. Germany has also set up a carbon market foundation with the primary goal of supporting programmatic climate protection initiatives. Despite all this, the two project mechanisms have made a crucial contribution to increasing climate protection awareness in developing and emerging countries and have initiated the development of emissions trading systems (in China, for example).

**© Responsible for this text:** Juliane Berger (Section I 2.1), Konrad Raeschke-Kessler (Section E 1.6) und Benno Hain (I 2.2).

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#### Climate change: global risks and the need to adapt

## The consequences of climate change observed to date

The Fifth Assessment Report from the IPCC (Intergovernmental Panel on Climate Change) reiterates that human activity is changing our climate, and that the risks faced by people and the natural world are already increasing today as a result. The following climate changes have been observed:

- The mean global surface temperature increased by around 0.85 °C between 1880 and 2012. Furthermore, the frequency of heat waves has risen in large parts of Europe, Asia and Australia, probably as a result of climate change.
- Extreme precipitation has occurred more frequently in some world regions since the 1950s. Damage from floods has also increased across the globe since the 1970s. In addition to climate change, other factors such as increasing population density and the accumulation of goods i.e. the general amassing and increase of material assets influence the extent of the damage caused in vulnerable regions.

Furthermore, climate change has an impact on human health, on ecosystems, on the supply of food and water, and on buildings and infrastructures. Climate change also heightens the risks presented by both urbanisation and the contamination of air and of water.

#### **Consequences of future climate change**

The following developments are among those that can be expected worldwide:

- An increased impact on human health is to be anticipated in many regions of the world. In the future, heat waves could increasingly lead to health problems and higher rates of mortality in Europe, for example. As a study by the German Weather Service (DWD) for the German Environment Agency (UBA) showed in early 2015, the rate of mortality due to coronary heart disease during heat waves had already increased by 10 to 15 percent on average between 2000 and 2010.
- Damage caused by heavy precipitation, periods of heat and drought and other extreme weather events are likely to increase in the future. This could also lead to adverse effects on the water and energy supply should the relevant infrastructures be affected.

• Some countries may experience future shortages in their food production and water supply. The consequences of climate change may also lead to a worsening of economic and social inequality.

These risks can be reduced, however. In urban areas, for example, specially designed streets, squares and bicycle paths can relieve the burden on the sewerage system by aiding the infiltration of surface runoff during periods of heavy precipitation. Urban green belts and green roofs can also help reduce the urban heat island effect in cities during heat waves.

Climate protection and adaptation complement one another. Ambitious climate protection is necessary to reduce the effects of climate change in the long term. At the same time, climate change adaptation is required to decrease the damage caused by existing and anticipated climate change. The earlier we take reduction measures into account alongside adaptation measures and non-climatic factors (such as urbanisation and demographic developments), the better we will be able to exploit opportunities for sustainable development and implement them at all planning levels.

## Planning and implementation of climate adaptation: the role of national governments

For the most part, climate adaptation has a direct local connection - the planning of green spaces in cities to improve the urban climate and the infiltration of rainwater runoff, for example. National governments have an important role to play in the planning and implementation of adaptive measures: they set political framework conditions; provide financial resources; help with data and information on climate changes, climate impacts and vulnerabilities; and support such implementation activities as the changing of planning procedures, the checking of technical norms and standards, and the coordination of regional adaptation activities ranging from a local to a multinational level.

It is important to coordinate the activities of various stakeholder groups on a national level and connect them with European and international activities (such as reporting and financing, for example).

• Responsible for this text: Achim Daschkeit, Petra Mahrenholz, Inke Schauser (Section I 1.6)





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#### The Paris Climate Agreement

#### All states sign a comprehensive agreement to limit the temperature rise under international law

Right from the outset, the chances of reaching a comprehensive international climate agreement were significantly better in Paris (2015) than they had been in Copenhagen (2009). The majority of nations stated in advance that they would be striving for a comprehensive deal on a new, globally effective, legally binding climate protection agreement in December 2015. The national processes to prepare each country's Intended Nationally Determined Contributions (INDCs) for the new agreement also sent out a positive message even before the conference began. The Member States of the UNFCCC used these INDCs to communicate the contributions they would be willing to make to reduce GHG emissions under the new agreement. Germany supported over 30 developing nations with the preparation of their INDCs as part of the International Climate Initiative (ICI). Climate protection is closely associated with the secure access to energy, and thus also with the opportunity for economic development, one of the highest priorities for developing and transition nations. Nevertheless, a decisive factor will be whether

or not countries take sustainable developmental paths that can also put a stop to climate change. As the transition nations now number among the biggest greenhouse gas emitters in the world, their contribution to emission reductions – alongside that of the classic industrialised nations – is essential.

The Paris Conference in late 2015 succeeded in setting down common climate interests in a global agreement. It was not only the first time that the 2-degree upper limit had been enshrined in an internationally binding settlement, but also the first time that efforts to limit the global temperature rise to 1.5 degrees had been formalised.

In order to achieve this long-term objective, the agreement aims to bring about a reversal and, therefore, a reduction in greenhouse gas emissions as soon as possible. It also intends to balance the greenhouse gas budget in the second half of the century. In real terms, this requires the decarbonisation of the world economy and thus a phasing-out of fossil fuels. This sends out a clear message that must be reflected in future actions and investments.

The agreement's dynamic approach is particularly welcome. All states have to put forward new targets every 5 years. These must be steadily progressive and must not allow nations to fall behind previously submitted goals. Prior to this process, a "global stocktake" must be carried out to see whether the international community is on track to achieving the agreement's overall goal of limiting the global temperature rise to significantly less than 2°C.

The form and modalities of this global stocktake will have to be worked out over the next few years. The new agreement also states that the international community will be tasked with determining the modalities and regulations for the transparency system (which is mandatory for all parties) and for the market mechanisms that have been adopted as part of the agreement.

It is also important not to ignore the Paris Agreement's work to strengthen market-based climate protection efforts. The agreement includes a (new) sustainability mechanism that is explicitly based on experience with previous market mechanisms (CDM and JI). This mechanism takes the essential demands of the EU into consideration in that it supports the contributions made by host countries and aims to contribute to real net emission reductions overall, and not just to carbon leakage. Moreover, the agreement makes provision for the possibility that states can transfer emission units internationally and have them taken into account as part of their inventory. This option forms part of the "cooperative approaches" and offers, among other things, the chance to link up various emissions trading systems. All of this additionally allows the Paris Agreement to send out an important message regarding the continuation of market-based climate protection measures that will also reach the attention of private stakeholders.

We will continue to work on the details of the new agreement and its implementation on both on an international and a national level in the next few years. The German Environment Agency will be able to contribute its expertise in many areas. Furthermore, we will support developing nations in building greenhouse gas inventories, for instance, by introducing them to our own inventory system and answering their questions.

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#### **The European Emissions Trading System**



#### **Strengthening and structural reforms**

The European Emissions Trading System (EU ETS) is the central instrument for climate protection in the energy and industrial sectors in Europe. It covers around 45 percent of greenhouse gas emissions across the EU. With its economic incentivising effect and its effective limitation of emissions via the cap on emission allowances, the ETS is designed to ensure that European climate protection goals are attained reliably and cost-efficiently.

However, high market surpluses of emission allowances and the resultant long-term depression of prices mean that the ETS currently has no significant controlling effect. The reason for these surpluses is, first and foremost, the insufficiently ambitious caps that were set in the third and - above all - the second trading period, in conjunction with the heavy use of cheaper project credits (CER/ERU). Emission levels, which were significantly lower than expected following the economic crisis, also play a major role.

The European Council of 24th October 2014 decided that the EU should reduce its greenhouse gas emissions by at least 40 percent by 2030 (in comparison to 1990 levels). To achieve this goal, the emissions trading cap shall be lowered more quickly than before, starting in the fourth trading period (from 2021). The Linear Reduction Factor – which determines how far the emission allowance budget is to be capped each year - shall rise from its current 1.74 percent to 2.2 percent.

Moreover, at a European level, the European Commission, the European Parliament and the EU Member States have all agreed to reform the EU Emissions Trading System via the introduction of a Market Stability Reserve (MSR). This will gradually remove the surpluses in the EU emissions trade and feed emission rights back into the market later on as required. The German Federal Government and the German Environment Agency took the position of demanding an ambitious design for the MSR very early on, so that they could play an active role in shaping negotiations and thus fulfil their goal of strengthening this central climate protection instrument. After all, a strong EU ETS price signal is an important foundation for the reduction in German emissions that the Federal Government is striving for (40 percent by 2020 compared to 1990 levels).

#### **Cornerstones of a reformed European Emissions Trading System**

The introduction of the MSR should remove existing surpluses and allow the Emissions Trading System to react more robustly to future fluctuations in demand.

The MSR essentially functions as follows: the auction volumes in the emissions trading market will automatically be capped from September for the following 12 months if the number of surplus credits exceeded a threshold of 833 million at the end of the previous year. This reduction in the auction volumes equates to 12 percent of the surplus. The non-auctioned emission allowances flow back into the MSR. Conversely, a fixed number of additional emission allowances (100 million) will be put up for auction if it has been determined that fewer than 400 million surplus emission allowances are available.

This cap on auction volumes will take effect in January 2019. In addition, the 900 million emission allowances that were withheld from 2014 to 2016 (referred to as backloaded allowances), and any allowances that were not allocated free of charge by the end of 2020 (surplus allowances) will be transferred directly to the

MSR. The European Commission originally suggested that the MSR begin in 2020 (with the first cap being set in 2021) and that the backloaded and surplus allowances be auctioned off. The agreement that has been reached thus greatly exceeds the initial proposal and will significantly strengthen the EU ETS prior to 2020.

Moreover, the German Environment Agency recommends that at least 1.6 billion emission allowances be permanently removed to quickly and – above all – sustainably correct the erroneous past estimates that led to overly high surpluses. Only then can we also be sure of attaining our mid- and long-term climate goals.

A further point of focus for the reform of the EU ETS arises from the question of which rules should apply to the industrial sector in future. On the one hand, there must be an effective way to stop energy-intensive production and resultant emissions being relocated to states that operate no comparably stringent climate protection measures (known as "carbon leakage"). On the other hand, ambitious reductions and, therefore, exacting emission standards (benchmarks) are required in the industrial sector to incentivise companies to make technological and efficiency-related developments. The most efficient production methods must be identified for this to take place. These questions are being resolved as part of the on-going negotiations on the amendment of the Emissions Trading Directive.

#### Climate protection in aviation

Change is also currently underway in the aviation sector. Since the EU expanded emissions trading to the aviation industry in 2012 - sending out a clear climate policy message in the process - there have been signs of movement in the previously unsuccessful attempts to bring a greater level of climate protection to international aviation. The International Civil Aviation Organization (ICAO) is currently developing a Global Market-Based Measure (GMBM) for international air transport that will be agreed upon in 2016.

The goal is to at least compensate for the increase in CO<sub>2</sub> emissions from 2020 via the purchase of certificates from other sectors. The mechanism for distributing compensation obligations among individual airlines is the most controversial aspect of the proposal. So that a vote can be taken on the measures at the ICAO's Assembly in autumn 2016, the specialised technical content must virtually be complete by the end of 2015. The UBA has been providing intensive specialist help in this regard.

In order to support the procedure taking place within the ICAO, the EU ETS will only apply to flights within Europe until 2016. Afterwards, its area of application will be redetermined based on the contents of the ICAO's decision; should the ICAO fail to come up with a satisfactory global regulation, it may also be extended to non-European flights once again. In any case, a successful ICAO procedure can only be a first step in limiting the climate impact of the aviation industry. In order to achieve a true reduction, more far-reaching steps are necessary that also take into account the fact that the effect of greenhouse gas emissions at the cruising altitude of commercial aircraft is around twice as large as at ground level. Air transport currently produces at least 5 % of global greenhouse gas emissions. The emissions from international aviation that are harmful to the environment grew by 86.4% from 1990 to 2012.

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#### Conclusion

Greenhouse gas emissions cannot continue to rise for much longer if the average global temperature increase is going to remain below two degrees Celsius. In fact, the total volume of emissions must decline as soon as possible - least-cost models assume that a peak is reached between 2010 and 2020. It is also important that we no longer make a distinction between the targets set for developing countries on the one hand and industrialised nations on the other. Our focus should be on a decisive, overarching reduction that naturally takes individual capabilities and responsibilities into account. Nevertheless, emerging economies should do just as much of their share for climate protection as the industrialised states. Many nations now recognise that climate protection ultimately lies in their own economic interests. By publishing its INDC at the start of 2015, the EU committed itself to an ambitious target of reducing emissions by at least 40 percent within its borders by 2030 (in comparison to 1990 levels). A further increase in this EU target via the accompanying use of such market-based climate protection instruments as the Emissions Trading System and the CDM would also be beneficial. Our long-term goal must be the attainment of a greenhouse gas-neutral economy, even in industrialised nations. A study from the UBA - "Germany 2050 - A Greenhouse Gas-Neutral Country" - demonstrated the achievability of this aim back in 2014.

# Nitrogen. Too much of a good thing?

Useful or harmful? A substance with many facets

Whenever a substance is discussed in terms of environmental protection, the general consensus is: less is more! This is the case with the greenhouse gas CO<sub>2</sub>, particulate matter in the air, heavy metals in the soil and the occurrence of active pharmaceutical ingredients and plant protection products in the water.

The response is somewhat different when it comes to nitrogen however. This is because nitrogen is an essential building block of life and a vital source of nutrients for all living things. The body of an adult who weighs 70 kg contains nearly 2 kg of nitrogen. Even the majority of the air we breathe consists of this element (78%). Moreover, nitrogen fertiliser increases yields from agriculture and in private gardens. Regions of the world that have too little nitrogen fertiliser at their disposal produce crop yields that are significantly lower than the soil and climate would allow. Bearing all this in mind, it can be hard to believe that this vital, widespread chemical element is implicated in some of the biggest environmental problems of our age.

Page 20-35

## What is nitrogen?

#### Nitrogen in the environment

The element nitrogen is essential for all life on earth. In order to act as a building block of life however, it must form chemical compounds with other elements and thus be converted into its reactive state. Despite being the principle component of our atmosphere, molecular atmospheric nitrogen cannot be used directly by most living organisms.

#### Nitrogen in the body



#### The release of nitrogen into the environment

The release of nitrogen into the environment has increased significantly along with the rising world population. The release of nitrogen



#### World population

Atmospheric concentration of nitrous oxide (N<sub>2</sub>O), a nitrogen compound that affects the climate



## The main cause: agriculture







#### Fertiliser and crop cultivation

Mineral and organic nitrogen fertilisers supply valuable nutrients for plants. They should be used according to the crops' requirements.

and vegetables



Nitrogen is an important element for all life on earth.



## Great at making connections – but not popular everywhere it goes

The element we call nitrogen is essential for all life on earth. To perform its role as a building block of life however, nitrogen must form chemical compounds with other elements. This is because, despite being the main constituent of the air we breathe, molecular atmospheric nitrogen cannot be used directly by most living things. This is not the case with reactive nitrogen however, the name used to refer to the element when it is bonded in various chemical compounds. Reactive nitrogen passes through the nitrogen cycle and occurs in a gaseous, dissolved or organic compound state, allowing it to be used equally efficiently by terrestrial and aquatic organisms alike. The global nitrogen cycle transports reactive nitrogen to nearly every corner of the planet.

Humans have been continually feeding nitrogen into this system for around a hundred years, particularly via the emission of nitrogen oxides from combustion and from the industrial synthesis of reactive nitrogen compounds via the Haber process (the synthesis of ammonia to create fertilisers). The latter technique is predominantly carried out to improve and intensify the production of plants.

On a global scale, the amount of reactive nitrogen has approximately doubled during this time period. This creates risks for humans and the environment almost everywhere on earth.<sup>1</sup> It endangers the quality of our air and water, and threatens human health and biodiversity as a result. Reactive nitrogen also contributes to climate change.

Risks to biodiversity arise when an overabundance of reactive nitrogen is present in ecosystems. This leads to the excessive growth of certain species and, as a consequence, to a reduced species diversity overall. This effect is known as "eutrophication", which comes from the Greek for "well nourished". It favours fast-growing, nutrient-loving plants that take up the light, water, nutrients and space needed for the growth and expansion of other plant varieties. This leads to the mass development of particular species that endanger the ecological equilibrium. The mass development of algae in bodies of water leads to oxygen depletion when the algae dies back. This is detrimental to both the fish fauna and organisms that live at the bottom of the water. As the Convention on

Biological Diversity (CBD) has also confirmed, nitrogen depositions represent one of the five main threats to biological diversity throughout the world – particularly so in temperate, boreal and alpine climate zones.<sup>2</sup>

The overabundance of nitrogenous nutrients is also a problem in coastal and marine ecosystems. In such areas, it not only leads to a reduced Secchi depth and a lack of oxygen, but also to the increased growth of algae and the higher incidence of algal species that produce and excrete toxins. These harm other marine organisms and can also affect humans, who can contract such problems as diarrhoeal illnesses via the consumption of bivalves that filter toxic algae. As well as damaging indigenous ecosystems, the eutrophication of seas can also affect fishing and tourism.

Nitrogenous nutrients – predominantly in the form of nitrate – cause problems in a different way when it comes to groundwater. This form of nitrogen enters the groundwater from over-fertilised fields and pastures. An overabundance of nitrate is detrimental to human health. This can become a particular issue in places where groundwater is used to provide the drinking water supply.

Unwanted nitrogen compounds in the air we breathe also have a detrimental impact on our health. Nitrogen dioxide gas is formed during the combustion of fossil fuels, e.g. by road traffic. It leads to the inflammation of airways and can increase the effect of other atmospheric pollutants. In addition, reactive nitrogen compounds in the air contribute to the formation of secondary particulate matter and ground-level ozone, both of which are harmful to human health. Ground-level ozone is also a noxious pollutant for plants and has a corrosive effect on stone, metal and synthetic materials in combination with nitrogenous acids in the atmosphere.

Last but not least, reactive nitrogen accelerates climate change in the form of nitrous oxide. Nitrous oxide is primarily created via reactive nitrogen conversion processes that take place in the soil and bodies of water. It is 265 times more damaging to the climate than carbon dioxide and causes around 6 % of climate change.<sup>3</sup>



#### The nitrogen cycle in Germany

Reactive nitrogen is very mobile and adaptable. It moves through the various environmental media in its different forms. Reactive nitrogen occurs in the atmosphere as e.g. ammonia, nitrogen dioxide, nitrous oxide and ammonium carbonate particles. In its dissolved state, it takes the form of ammonium and nitrate, which reach the soil via precipitation and subsequently enter the groundwater and surface water via leaching. Alongside the anthropogenic processes that convert atmospheric nitrogen into its reactive form, there are also processes that transform reactive nitrogen back into harmless atmospheric nitrogen. These include bacterial denitrification (in which nitrate is reduced to form N2) and the selective catalytic reduction (SCR) of nitrogen oxides in engine exhaust fumes. Used intelligently, these processes can effectively reduce the amount of reactive nitrogen in the cycle. Denitrification is a microbial process that takes place in soil and bodies of water. Bacteria convert nitrogen oxide into forms that no longer influence the environment. The process is deliberately used in wastewater treatment to remove reactive nitrogen from the water.

Every year, significantly more reactive nitrogen enters the nitrogen cycle in Germany than can currently be removed. We therefore urgently need to decrease our nitrogen emissions in order to reduce the effects of anthropogenic nitrogen depositions. In order to prioritise the necessary courses of action, the German Environment Agency has recently compiled information on where the various nitrogen compounds that enter the cycle come from, and how much originates from the different sectors of the economy.<sup>4</sup> The most notable pathways to entry are:

- the industrial fixation of atmospheric nitrogen via the Haber process for the production of ammonia,
- the importation of reactive nitrogen via proteinaceous animal feed (particularly soya),
  biological nitrogen fixation in our fields via the cultivation of legumes,
- the combustion of fossil fuels, and
- the transboundary transportation of nitrogenous air and water pollutants via rivers and the atmosphere.

The analysis concluded that nearly two thirds of the emissions in our air, soil and water come from agriculture. The rest is divided up between the transport, industrial and energy sectors and waste/wastewater management (around 10 - 15% each). This was not always the case: although overall emissions have declined over the last two decades, the relative proportion of agricultural emissions has significantly increased over the last 20 years. In the 1990s, for instance, less than 50% of the reactive nitrogen compound emissions came from agriculture.<sup>5</sup> This is not to say that agricultural emissions have drastically increased - indeed, they have even seen slight reductions. In contrast however, the wastewater and transport sectors have been successful in reducing their emissions to a considerable degree via the implementation of technological solutions, whereas the ammonia emissions from agriculture have remained largely consistent for over 20 years. After initially plummeting for a time in the early 1990s as a result of the collapse of cattle farming in the new German states (Länder), the balances in the national nitrogen budget are now only decreasing very slowly today.

#### Too much nitrogen endangers ecological equilibrium

It is not just climate change and the loss of biological diversity that have already crossed a critical threshold, putting the ecological equilibrium of the inhabited earth in danger: nitrogen depositions have also reached this point. This was the surprising message from a 2009 investigation by renowned scientists on what are known as the "planetary boundaries".<sup>6</sup> Excessive global nitrogen levels are predominantly caused by intensive agriculture in a handful of regions, including Central Europe. This means that we are not only obliged to take action to combat the environmental problems in our region – we must also face up to the risk on a global scale.

## **Excessive nitrogen depositions from** agriculture

Increased concentrations of such plant nutrients as nitrogen and phosphorus lead to the increased growth of algae in surface waters. The consequences of this are turbidity and - following the biological decomposition of the plant biomass - oxygen depletion and temporary oxygen deficiencies in the water. This leads to changes in the composition of the typical aquatic flora and fauna. For this reason, many of the rivers and lakes in Germany and Europe cannot currently achieve the "good ecological status" that the EU Water Framework Directive (EU WFD) is striving to attain. Although nutrients do enter rivers from wastewater treatment plants here and there, they predominantly arise via diffuse surface run-off from the soil on adjacent land and the infiltration of contaminated groundwater.

Alongside phosphate, nitrate is responsible for the fact that all of the coastal waters and 60%of the lakes in Germany can still not attain the "good ecological status" today. The nitrate load in rivers has been reduced over the last few decades thanks to the removal of nitrogen in wastewater treatment plants; the increasing numbers of people connected to wastewater treatment plants has also had a positive effect. Nitrogen depositions in surface water in Germany amounted to 600,000 t/a from 2006 to 2008; this represented a reduction of 42% compared to the period from 1983 to 1987 when the amount of nitrogen depositions coming from wastewater treatment plants declined by 77 %. In contrast, the depositions from agriculture were only reduced by 23 % - this sector produces 80% of all the remaining nitrogen depositions in the surface water today. The situation does not look any better in other EU countries, either. The average nitrate concentration in European watercourses only decreased by approximately 11% between 1992 and 2010 (from 2.5 mg/l N to 2.2 mg/l N). This is too little to achieve the goals set by the EU WFD.

The groundwater supply is primarily contaminated with nitrate. Groundwater is said to have a "good chemical status" when it contains less than 50 mg/l nitrate and under 0.1  $\mu$ g/l of plant protection products, and when it complies with the threshold values for relevant pollutants (specified in the EU WFD). At present, around 37 % of all groundwater bodies in Germany do not attain this good status. If one examines nitrate alone, 27 % of all groundwater bodies in Germany have a "bad chemical status" due to contamination with this substance. The main cause of nitrate pollution is depositions from agriculture; a similar situation is also seen in other EU countries with intensive agricultural production. Although the nitrate load in the groundwater slowly began to decrease in Germany before c. 2007, the data now show renewed increases, particularly in certain regions. Among other reasons, this can be attributed to the increased growth of energy crops (particularly maize) and the ploughing up of grassland that has partially been carried out to accommodate them. The impact on groundwater nitrate concentrations can be seriously delayed however, as the flow time from the surface down to the groundwater via the non-waterlogged topsoil layers can often amount to years or even decades. Estimates range from 4 to 8 years (Germany, Hungary) to several decades (the Netherlands).

Comparing the land use in the areas around groundwater measuring stations reveals the major causes of nitrate in groundwater. The lowest levels occur wherever woodland is dominant; nitrate levels are higher than 50 mg/l at fewer than 5 % of these measuring stations. In areas of grassland (pastures and meadows), the number of stations with a high level of nitrate contamination rises to 6.5 %. Wherever



fields and residential areas prevail, the proportion of measuring stations with nitrate values over 50 mg/l rises to 23 % (fields) and 13 % (residential). Agriculture is therefore of great significance with regard to groundwater nitrate contamination.

This relationship has been known for a long time. As early as 1991, the EU issued the Directive on Fighting Water Pollution from Agricultural Nitrates (the Nitrates Directive, 91/676/ EEC). This demands the observance of "good agricultural practice" and the implementation of an action programme. The directive was enforced throughout Germany via the Fertiliser Ordinance (DüV) and the regulations of the German states (Länder) for the storage of liquid manure. Both of these legal areas should include stricter environmental requirements in the future. Appropriate regulations – and an amended Fertiliser Ordinance in particular - are currently being prepared and should enter into force in 2016.

As well as implementing the Fertiliser Ordinance, further measures will be carried out by the German states (Länder) in the course of the second river basin management planning process in the context of implementing the EU WFD. This will be done in order to achieve the targets of the EU WFD. The German Working Group on Water Issues (LAWA) calculates that the required reductions in nitrogen depositions in the large German river basins stand at between 6% (Rhine) and 40% (Elbe). The designation of riparian strips and the renaturation of littoral zones and flood plains could significantly improve the nutrient retention in the areas around smaller tributaries that lead into larger rivers.



#### Algal bloom and "dead zones": the North and Baltic Seas suffer from an overabundance of nutrients

Alongside overfishing, the overabundance of nitrogen depositions is currently the biggest ecological problem in the North and Baltic Seas. The resultant eutrophication (an excess of nutrients) in these coastal and marine waters leads to a range of negative consequences for marine ecosystems (e.g. zones with oxygen deficiency, toxic algal blooms, and harm to animals and aquatic plants that live on the seabed). In the Baltic Sea, the spread of the so-called "dead zones" - areas in which life is no longer possible on the seabed due to the lack of oxygen - has increased more than tenfold over the last 115 years.7 Eutrophication is often the predominant or sole reason that marine waters do not attain a "good environmental status" in accordance with the Marine Strategy Framework Directive (MSFD).

The nitrate depositions in the North and Baltic Seas predominantly originate from agriculture. About 75% is transported via rivers. Around a quarter of the nitrogen is introduced from the atmosphere, and primarily comes from agriculture (ammonia from livestock farming and fertiliser application), shipping, road traffic, power stations and industry.

In order to fight eutrophication, the regional Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") and the Baltic Marine Environment Protection Commission (HELCOM) set concrete reduction targets for nitrogen depositions. The second International Conference on the Protection of the North Sea (INK) in London and the OSPAR Treaty States had already decided on strategies to reduce overall nutrient depositions in marine waters and nitrogen depositions by 50% (in comparison to 1985 levels) back in the 1980s and 1990s. Between 1985 and 2005, Germany was able to reduce the nitrogen depositions flowing from rivers (known as riverine nitrate depositions) into the North Sea by 48% and into the Baltic Sea by 50%. In combination with a much higher decline in phosphate depositions (due to phosphate elimination in wastewater treatment plants and the introduction of phosphate-free detergents), these reductions are slowly allowing some of the effects of eutrophication to subside. The return of seagrass to the Wadden Sea has been observed, for example. Nevertheless, recent assessments of the state of eutrophication show that further reductions on a similar scale are necessary to achieve the targets set by the MSFD in the North and Baltic Seas.

The Baltic Sea countries adopted the Baltic Sea Action Plan in 2007 in reaction to the serious, sustained eutrophication problems in the Baltic Sea. This plan saw them agree upon ambitious commitments to reduce nutrient depositions. These underwent scientific revision in 2012, whereby atmospheric nitrogen depositions were also taken into account alongside riverine depositions for the very first time. At the HELCOM Ministerial Conference in October 2013, Germany pledged to reduce its nitrogen depositions into the Baltic Sea by 7,670 t. Nearly 75% of these promised reductions have to be achieved by decreasing atmospheric nitrogen depositions. The emission reduction targets agreed upon by the Baltic Sea countries (among others) under the Gothenburg Protocol of the UNECE must also be attained in full. In addition, measures must be implemented to reduce the nitrogen emissions from shipping. This goal could be aided by the introduction of a Nitrogen Oxide Emission Control Area (NECA) in the North and Baltic Seas which could only be entered by ships equipped with state-of-the-art exhaust gas purification technology.

## Many terrestrial ecosystems cannot tolerate any nitrogen

Ecosystems that are sensitive to nitrogen depositions include: nutrient-poor meadows and pastures; broadleaf, coniferous and mixed forests; natural grasslands; moors and heathlands; and inland marshes and peat bogs. Reactive nitrogen compounds are introduced into these ecosystems via the air. Once there, they act as nutrients in concentrations that favour the growth of nutrient-loving plants, which drive the nutrient-sensitive plants out of these naturally nutrient-poor locations in turn. This can also indirectly affect many animal species that are dependent on particular nutrient-sensitive types of plant. In addition, eutrophication increases the vulnerability of many plant varieties to such stress factors as frost, drought and herbivorous pests. Many varieties of plant are included on the "Red List" due to the effects of increased nutrient depositions.9 Around two thirds of all natural habitats in the EU are over-fertilised, and nearly half of the ecosystems are not sufficiently protected from acidification.

Atmospheric pollution from such reactive nitrogen compounds as ammonia (NH3) and nitrogen oxide (NO<sub>2</sub>) is predominantly responsible for this eutrophication and acidification. A significant quantity of these compounds is transported over great distances via the atmosphere, and can thus only be efficiently reduced by way of international agreements. Nevertheless, local emitters also significantly contribute to the endangering of nutrient-sensitive terrestrial ecosystems in pollution hotspots. This is particularly true of intensive livestock farming. Nitrogen emissions must therefore be reduced in two ways: firstly, by restricting the overall annual levels of harmful atmospheric pollutant emissions (regulated by the EU National



Emission Ceilings (NEC) Directive and by the Gothenburg Protocol of the Geneva Convention on Long-Range Transboundary Air Pollution); and, secondly, via the reduction of pollutant emissions direct at their source, i. e. at industrial installations. The latter is achieved by way of the Industrial Emissions Directive and the associated Reference Documents on Best Available Techniques.

The EU NEC Directive<sup>10</sup> specifies emission ceilings for certain atmospheric pollutants. The EU Member States have not been allowed to exceed these limits since 2010 (Germany's limit for ammonia is 550,000 t, for example). Furthermore, the Geneva Convention on Long-Range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE) agreed to limit annual pollutant emissions in the revised version of the Gothenburg Protocol (2012). These obligations to reduce emissions must be satisfied by 2020. The targets they include for ammonia emissions are less ambitious, however. The EU is also currently discussing a revised version of the NEC Directive. It is expected that a new Directive will contain emission limits for 2030. These are currently still under negotiation.

Intensive livestock farming facilities with more than 2,000 places for production pigs, more than 750 places for sows and more than 40,000 places for poultry are particular local pollution hotspots for ammonia and ammonium compounds. These installations fall within the scope of the Industrial Emissions Directive<sup>11</sup> (IE Directive), which calls for the obligatory implementation of Best Available Techniques, the adherence to emission limits and the regular monitoring of animal facilities. The Best Available Techniques are described in Reference Documents that were compiled via the consensus process by a Technical Working Group (TWG) with experts from the EU Member States. The old Reference Document on Best Available

A one-percent reduction in the protein content of feed for both pigs and poultry would lead to a ten-percent decrease in nitrogen and ammonia emissions.



#### Nitrogen oxides in the air

Nitrogen dioxide (NO<sub>2</sub>) is the reactive nitrogen compound in the air we breathe that is harmful to human health. NO, is one of the nitrogen oxides (alongside nitrogen monoxide (NO)). It is formed from the nitrogen in the atmosphere during combustion processes. Combustion primarily releases NO, which can then further react in the atmosphere to form NO<sub>2</sub>. In order to protect human health, an annual average limit of 40  $\mu g/m^3$  and an average hourly limit of  $200 \,\mu g/m^3$  has been in force within the European Union since 2010. These limits may not be exceeded more than 18 times in a calendar year. In some regions, the deadline for compliance with these thresholds has been extended by five years. Observance of the limits has been required throughout Germany since 2015.

Techniques for the "Intensive Rearing of Poultry and Pigs" from July 2003 - a document which is currently still valid - was based on the methods employed in Europe for the low-emission management, storage, treatment and application of slurry and manure. Work has been in progress on a new version of the Best Available Technique Reference Document (BREF) for the "Intensive Rearing of Poultry and Pigs" for the last few years. As well as the reduction of pollutants (nitrogen, phosphorous, odours, dust and bioaerosols), this version also takes the preservation of resources and - more recently animal welfare into consideration. The largest emitter of ammonia is cattle farming. In contrast to the EU Commission's original draft however, this sector is not addressed in the new Reference Document. Best Available Technique (BAT) conclusions are currently being derived from the revised BREF on intensive livestock farming. These conclusions are expected to be published in the Official Journal of the European Union in 2016 and will thus become binding.

A combination of two feeding strategies turns out to be one of the most efficient options for reducing the environmental impact of agricultural practices:

- the improvement of the properties of animal fodder for nutrient-adapted feeding via a low protein and phosphorus content, and
- the composition of a feed ration that corresponds to the rearing stages of animals (multiphase feeding).

Reducing the protein content of the feed for both pigs and poultry by just one percent leads to a ten percent reduction in nitrogen and ammonia emissions. Great potential ammonia reductions can also be made in cattle and poultry farming via the storage and application of excrement in the form of organic fertilisers. An additional key area of focus in pig farming is the stalls in which the animals live. For this reason, over 1,000 large pigsties (with space for >500 animals) are now equipped with waste air purification systems in Germany.

The state-of-the-art technology for the storage and application of organic fertilisers includes covered slurry stores and the use of a trailing hose, a trailing shoe and injection techniques for low-emission methods of slurry application. The immediate incorporation of slurry and manure (<1 hour) after being spread on bare soil makes a significant contribution to the reduction of ammonia.

All of these measures represent the current benchmarks for environmental standards in agriculture today. To date however, they have not been sufficiently codified as environmental protection requirements in the relevant regulations.

## A question of form: nitrogen in the atmosphere

Nearly 80% of the air we breathe consists of nitrogen, albeit primarily in the form of N2, a chemically inert compound with a low level of reactivity that cannot be used by most living organisms. The exceptions to this rule include legumes (pulses) and certain types of tree (e.g. alder). These can carry out nitrogen fixation and use it for nutrition thanks to their symbiotic relationship with rhizobia and actinomyces bacteria. Chemically reactive nitrogen oxide is also released into the atmosphere, predominantly via combustion processes in the energy sector and road traffic. In many places, this occurs at a rate that is hazardous to human health. This can be confirmed by examining measured concentrations. The annual average nitrogen oxide limit is exceeded at most inner-city traffic measuring stations, for instance, which have seen average concentrations of between 40 and  $50 \,\mu\text{g/m}^3$  in recent years. The annual limit was also found to have been exceeded at 60 - 70%of these stations. Moreover, the hourly average limit of 200  $\mu$ g/m<sup>3</sup> was surpassed at around 20% of all measuring stations near road traffic; approximately 2% of these stations even saw their limits exceeded by a factor of 18. Away from the busier streets, the concentrations of NO<sub>2</sub> drop to below 30  $\mu$ g/m<sup>3</sup> on average in cities; the limits at these sites have only been exceeded in isolated cases in recent years.<sup>12</sup> According to an analysis by the European Environment Agency however, Germany has the highest concentrations of NO<sub>2</sub> in Europe.<sup>13</sup>

The high concentrations of  $NO_2$  at measuring stations near road traffic are predominantly caused by motor vehicles. According to an extensive analysis of Germany's clean air plans, local motor vehicle traffic creates an average of 64 % of the  $NO_2$  pollution in cities. Heating buildings adds 7 %, industry contributes 3 %, and a further 21 % is caused by the transportation of pollutants from a greater distance away.<sup>14</sup>

Measures for the reduction of inner-city NO<sub>2</sub> concentrations must therefore predominantly address motor vehicle traffic. An important instrument in this regard is made up of the Euro emission standards that apply throughout the EU. These standards are constantly updated for new vehicles in accordance with the ever-advancing state of exhaust gas purification technologies.

Since September 2015, passenger cars have been required to comply with the Euro 6 emission standard when they are first registered. This standard lowered the nitrogen oxide emission limit for diesel cars from 180 mg/km (set by Euro 5, the previous standard) to 80 mg/km. The limit for cars with petrol engines remains unchanged at 60 mg/km. Adherence to emission limits is checked for each class of vehicle using measurements based on a pre-determined driving cycle. This does not sufficiently replicate driving conditions experienced during real-world operation, however. A new measurement procedure that measures the real-world emissions of Euro 6 diesel passenger cars on the road has yielded values that were seven times higher on average than the Euro 6 standard.<sup>15</sup> This discrepancy is even more significant in diesel cars, as the proportion of NO<sub>2</sub> they emit directly is particularly high. For this reason, an additional test procedure is currently under discussion in the EU. This process will take place under real-world conditions, as already occurs with heavy-duty vehicles today. This is the only way to guarantee that the tightening of emission standards actually leads to significantly reduced nitrogen oxide emissions in cities. Environmental zones that can only be entered by vehicles which attain a minimum standard of exhaust purification can accelerate the renewal of the fleet of vehicles on the road. The assignment of registration plates in various colours that are used to regulate entry into environmental zones is primarily based on the emission standards.

The legislative authority is also turning its attention to other sectors as well as road traffic. One example of this on a European level is the Industrial Emissions Directive (2010/75/EU). This forms the basis for specifying the best available techniques for the various sectors of industry in order to achieve such goals as reducing the emission of nitrogen oxides into the air.

#### Diesel cars emit the most NO,



Source: UBA/TREMOD 5.61

#### Nitrogen management helps bring about reductions

In terms of arable farming and crop cultivation, nitrogen is what is known as a macronutrient. Other macronutrients include phosphorus, potassium and magnesium. All nutrients must be present in sufficient amounts and in balanced ratios during the growth and ripening stages of plants in order to guarantee optimal growth, high yields and good quality crops.

In past centuries, nitrogen could only be added to the soil via animal excrement (generally in the form of manure), green manures or legumes (pulses, clover, lucerne/alfalfa, lupines, etc.). It was only with the invention of the Haber process in 1910 (for the synthesis of ammonia) and the Ostwald process (the oxidation of ammonia into nitric acid, the precursor of nitrates) that it became possible to convert inert molecular nitrogen from the air into reactive, plant-available compounds and create what are known as mineral fertilisers (synthetic fertilisers) on an industrial scale. The widespread use of mineral fertilisers was one of the prerequisites for the enormous increase in agricultural yields after the Second World War. It thus contributed to overcoming the hunger and lack of resources experienced during wartime and the post-war vears.

Before the Haber process came along, common fertilisers included Chile saltpeter (sodium nitrate) and guano (seabird excrement) that were harvested in South America.

invention of the Haber process for the synthesis of ammonia, people used guano – the excrement of South American sea birds – as a fertiliser.

Before the

"God bless you, you splendid birds on the far-off Guano Coast – whatever my countryman Hegel\* says, you produce the very finest manure!" (Joseph Viktor von Scheffel, 1826 – 1886) \*\*The philosopher Hegel was known for his notoriously anti-American attitude."



This intensified agricultural use of nitrogen fertilisers has led to an overabundance of nitrogen in the environment, however. As explained above, this causes a range of negative effects. Measures to improve the N efficiency of agriculture must therefore be refined and implemented. In addition, the levels of excess nitrogen need to be reduced and nutrient discharges should be minimised.

The situation varies greatly from region to region, as mineral nitrogen fertilisers cost money and are therefore generally used in a targeted, efficient manner. Farming operations that only cultivate plants (cash crop farms) usually exhibit low nitrogen excesses per hectare of agricultural land. Particular exceptions to this rule include such areas of specialist cultivation as the intensive vegetable farms in the Upper Rhine and the Cologne-Aachen Bay. Regions in which intensive livestock farming takes place in a very concentrated area (and in which crops are largely grown to feed the animals) are especially problematic. Principal examples of such regions include North Rhine-Westphalia and Lower Saxony. The amounts of animal faeces and urine (slurry) that are produced and spread on the land in these areas often exceed the levels required for plant nutrition. These regions display the highest levels of environmental problems caused by nitrogen as a result.



#### Measures for increasing N efficiency

- Precision agriculture: improved processes for predicting fertiliser requirements (various techniques including Nmin and electro-ultrafiltration); the adjustment of apportioned fertiliser applications based on current plant requirements (the use of N-sensors that determine the chlorophyll content in order to calculate the present nitrogen requirement of the crop); and subarea/subplot-specific cultivation on the basis of high-resolution soil and yield maps.
- Optimal management and utilisation of available organic fertiliser from animals (slurry, manure) with the exclusive aim of fulfilling the needs of crop production (i.e. no waste disposal); low-loss application techniques using modern equipment; instant incorporation into uncultivated soil.
- Optimisation of crop rotations and greater attention paid to the after-effects of nitrogen (regarding rapeseed, for example).
- Avoidance of longer bare fallow periods; planting cover crops; growing catch crops to reduce nitrogen leaching.
- Humus management and soil tillage adapted to each site for optimal soil structure and good root penetration. This gives the plants better access to the available nutrients in the soil, and also allows them to extract nutrients from deeper soil strata.
- Further advances in cultivation and varietal adaptation to each location.
- The refinement of nutrient-efficient cultivation techniques (e.g. strip tillage with subsurface fertiliser application; ammonium-depot fertilisation; CULTAN, etc.)

The prerequisites for the comprehensive implementation of measures to increase N efficiency include a more advanced level of training for the people involved. This should be supplemented with highly qualified consultancy services and practice-based agricultural research that efficiently implements its results in real-world, practical applications. Furthermore, certain aspects of the quality standards for agricultural produce need to be examined. The requirement for a 14 % protein (gluten) content in bread wheat (on pain of price reductions) often provokes a late application of nitrogen fertiliser that is problematic for the environment. In light of modern baking technology, this target seems controversial among experts and should be revisited.

#### Figure 1

#### **Development of Domestic Sales of Mineral Fertilisers**



Source: BMELV

#### Figure 2

#### Nitrogen balance from organic fertilisers



N max limit 170 kgN/ha under 40 40 to <80 80 to <120 120 to <160 160 to <170 170 to <180 180 and up

Source: DLG Mitteilungen 3/2014

#### Figure 3

#### Phosphate balance from organic fertilisers



Source: DLG Mitteilungen 3/2014

## The Common Agricultural Policy has not exhausted the available room for manoeuvre

DThe EU's Common Agricultural Policy (CAP) sets out the political support framework for agriculture in the Member States. Many decisions that are important for German farmers are now made in Brussels instead of Berlin.

The CAP currently consists of two pillars. The first pillar involves direct payments to agricultural operations ("subsidies") and market intervention measures (essentially a safety net against excessive price fluctuations). The second pillar concerns measures for the promotion of rural development.

In terms of direct payments (first pillar), receipt of the Basic Payment Scheme (70% of the overall amount) is dependent – among other things - on the fulfilment of environmental protection obligations ("cross-compliance"). These obligations more or less represent good standards of professional practice. Greening criteria (linked to 30% of the payment) have also been in force since 2015. These requirements go beyond good professional practice, and include crop diversification, the conservation of permanent grassland, and the allocation of 5 % of farmland (expected to rise to 7 % from 2018) as Ecological Focus Areas (EFAs). Measures to promote rural development (second pillar) include the agri-environment climate scheme, which involves the promotion of organic farming.

The CAP has a significant influence on the factors of production, and thus also the levels of nitrogen used as agricultural fertiliser. At one time, the CAP gave direct incentives for the high use of nitrogen by engaging in product price support measures and linking payments to the amount of products produced. Direct payments were reorganised in Germany in 2000, however. They are now linked solely to the area of land in use, independent of what and how much is cultivated there – the regulation of these factors is left up to the market. This decoupling was intended to reduce the pressure to intensify. The data for Germany show that the trend for using increasing amounts of mineral fertiliser that was observed up until the year 2000 has been reversed, albeit only to a small degree.

The newly implemented area-based direct payments have not helped combat the high accumulation of nutrients in intensive livestock farming (a method of production which is often carried out in limited space). Just as before, areas of intensive livestock production are still characterised by high excesses of nitrogen (N) and phosphorus (P). In recent times, additional excesses have arisen because of digestate (produced during biogas production), which is also applied to agricultural land. The Fertiliser Ordinance, which is currently being revised, must formulate strict standards in this regard and implement them effectively.

Among other things, greening is intended to help achieve the effective conservation of permanent grasslands and combat the decrease in grassland areas that has been seen in recent years. When grasslands are ploughed up, a great deal of humus is removed. Some of the nutrient excesses that are released in the process leach into the groundwater. Efficient grassland conservation should therefore at least counteract any further increases in nitrate depositions. The provision of Ecological Focus Areas on farmland is a further greening criterion. Catch crops and undersown crops are also recognised (though they are given a lower weighting). Nitrate that would otherwise leach away is caught in this plant cover, which holds onto it throughout the winter leaching period and beyond. In this way, these crops protect the groundwater and increase nitrogen efficiency. This allows savings to be made in spring fertiliser application without decreasing yields.

Rural development measures can be funded via the second pillar of the CAP. This includes supporting voluntary agri-environment climate schemes from national programmes that are co-financed by the EU. These schemes for rural development can involve extensive grassland and buffer strips, for example, and include the maintenance of, and conversion to, organic agriculture. The latter in particular must deal with nitrogen very efficiently as - in contrast to conventional farming - it does not allow the use of mineral fertilisers. As a result, the groundwater under organic farms is generally less contaminated with nitrate. Some water companies deliberately encourage organic farming in their water catchment areas, including Munich's water supply in the Mangfall Valley and the Canitz water resource of the Leipzig waterworks.

The range of support on offer extends from nitrogen management right through to the storage and application of organic fertilisers (liquid manure, slurry and dung). The second pillar is notoriously underfinanced, however, Although it is possible to redeploy finances from the first to the second pillar, this opportunity has not been fully exploited. EU law permits up to 15% of the resources to be transferred; in accordance with a decision made by the Conference of Agriculture Ministers of the German Federation and States (Länder) in November 2013, however, Germany contents itself with reallocating just 4.5 %. There is significant potential for improvement here from an environmental point of view.

## Everyone can do their bit: changing the way we eat

Our lifestyles also influence the emission of reactive nitrogen into the environment. This is particularly true of nutrition, as the production and consumption of foodstuffs in Germany cause up to 30% of all environment effects; this means that our eating habits come with a significant ecological rucksack. High levels of meat consumption, eating non-seasonal produce, and the loss and waste of food all have a particularly negative impact on the environment.<sup>16</sup>

Eating fewer sources of animal protein – i.e.

less meat and fewer eggs and dairy products – would make a contribution to protecting both the climate and the environment. Significantly greater amounts of nutrients and energy are required per kilo to produce animal-based foods than plant-based foods. Buying agricultural produce from organic farms not only has the advantage that they contain practically no chemical residues – in many cases, organic products are also linked to the lower deposition of nitrogen in the environment, as they are produced without the use of mineral fertilisers.<sup>17</sup>

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that, of the

Saving the environment is not just a question of what we eat, however - we must also pay attention to what we do not eat. Studies show that, of the c. 456 kg of food purchased per person every year, around 18% – or approximately 81 kg – is thrown away. At least half of this food could still have been eaten. This not only wastes valuable resources used for the production of the food (e.g. water and energy), but also the resources required for the treatment and disposal of the waste later on. The exact environmental impact caused by the mountain of wasted food is highly dependent on the composition of the waste itself. Measures to avoid food waste [see the article "Waste not, want not" in this publication] should therefore also pay particular attention to foods that are produced using protein from animal sources, as these are responsible for more nitrogen emissions.

Useful tips and tricks on how users can avoid food waste are important. Nevertheless, consumers are not solely to blame for the food waste problem. The retail market must also rethink its requirements regarding the flawlessness, size and shape of fruit and vegetables: these specifications often lead to edible foodstuffs being left on the fields because they do not fill the usual commercial criteria. Various initiatives are working to ensure that any produce which does not correspond to the usual "standard design" is also valued as edible food.<sup>18</sup>

Efforts to increase the value of this food and work against its devaluation are – and will remain – an important starting point. One way this goal can be achieved is by letting people get to grips with the available information and knowledge first-hand in a practical manner that engages all of their senses. Children and young people can "lend a hand"<sup>19</sup> on the fields, for instance, and thus develop a different relationship with food and the issue of nutrition overall.

Numerous urban gardening initiatives and the production of food on a very small scale in cities all help contribute to overcoming our increasing alienation from our food and its origins. Community Supported Agriculture (CSA) schemes are also enjoying a growing level of popularity.<sup>20</sup> High levels of meat consumption, eating non-seasonal produce, and the loss and waste of food all have a particularly negative effect on the deposition of reactive nitrogen in the environment.







## The search for an integrated strategy

There is a growing realisation in the public and political consciousness that the over-fertilisation of the environment not only allows stinging nettles to flourish, but also causes significant local and global effects that impact aquatic and terrestrial ecosystems and are detrimental to human health. Merely treating water to make it drinkable is no real solution. Our goal must be to view our water and soil as resources and ecosystems and protect them accordingly in a sustainable way. The legally codified limits represent the essential foundations for these conservation efforts.

The necessity of reducing reactive nitrogen levels in the environment has now been incorporated into numerous international agreements that aim to preserve individual protected natural resources - OSPAR, HELCOM, CLRTAP, the CBD and, last but not least, the Kyoto Protocol have already been mentioned in this report. However, there is a danger that these agreements will mean that nitrogen is only ever seen as just one risk among many. This makes the coordination and prioritisation of the most important measures more difficult.

Various European and international networks of scientists and players in the political sphere are now calling increasing attention to the close interrelations within the issue and are attempting to develop supraregional and cross-media solutions. Founded in 2002, the International Nitrogen Initiative (INI) has five regional centres on the five continents that promote the development of regional solutions and their integration into a common strategy.

In its special report on nitrogen,<sup>21</sup> the German Advisory Council on the Environment also stressed the need for an integrated international strategy. It stated that such a strategy should gather together environmental targets relevant to the nitrogen problem and evaluate, compile and prioritise existing measures and regulations for nitrogen reduction. The implementation of this strategy should also be supported via an ambitious programme of measures and regular checks to make sure that the targets have been reached. The German Environment Agency supports these points of view. Cost efficiencies and reductions that are implemented as early as possible in the nitrogen cascade are also important criteria for identifying the most urgent measures that need to be taken.

#### Conclusion

Reactive nitrogen causes numerous environmental and health problems in the form of various chemical compounds. This problem can only be confronted using an integrated approach that includes all sources of reactive nitrogen and brings about a rigorous reduction of depositions.

As reactive nitrogen primarily comes from combustion processes and agricultural activities, these domains represent the greatest potential for improvement. As far as using fossil sources of energy for the production of electricity is concerned, all of the possible technological options for reducing emissions

have been exhausted. Nevertheless, the transition to renewable energy from the wind and the sun will make a substantial contribution to the reduction of nitrogen oxide emissions from this industrial sector. There are also things we can all do to help: petrol engines emit far less nitrogen oxide than diesel vehicles and a reduced-meat diet is linked to significantly lower depositions of reactive nitrogen in the environment.

All of these steps are not enough to achieve a satisfactory environmental status however, if agriculture does not also play its part. After all, it is the largest source of nitrogen emissions with the highest potential for reductions. As well as bringing about a change in management practices (e.g. in terms of animal feed and the application of fertilisers), structural alterations are also required in this sector: an appropriately large area of agricultural land must be available on which to spread the amount of liquid manure created by intensive livestock farms. Some regions currently exceed the maximum viable livestock population in this respect by a large margin. The support from the Common Agricultural Policy offers

further regulatory tools for facing up to the nitrogen problem. These must be used rigorously within the available room to manoeuvre on a national level however, so that we can stand up at the earliest opportunity and confidently say: nitrate in the groundwater, carpets of algae on the coast, and risks to our health from polluted air? Those are all a thing of the past ...

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## Waste not, want not

How the modern circular economy works

The growing level of global consumption requires us to rethink how we deal with natural resources. A circular economy – one which fully integrates all aspects ranging from product design, sustainable production methods and patterns of consumption to recycling – makes significant contributions to resource conservation.

Page 38-57

## What is waste?

#### Amount of municipal waste per capita, 2012



#### municipal waste in Germany, 2013



#### What are the causes of food waste in Europe? 2010, figures in percent





# the environment

## The topsoil is washed or blown









#### WASTE NOT, WANT NOT

Economic development in Germany has long been characterised by rising industrial production and an expanding service industry. This has naturally been accompanied by greater pressures on the environment. It has been possible to reduce or contain these environmental effects in many sectors, however, as environmental technology has become more advanced, and organisations have made contributions to protecting the environment within their companies and have become more efficient at dealing with energy and raw materials.

On a macroeconomic scale, many of the climate protection gains made in Germany have been reversed or even eclipsed, however, as both the volume and variety of products being produced has risen simultaneously, and manufacturing has increasingly been transferred abroad. An example is provided by electric devices – although each individual device has become significantly more efficient, many more devices have been sold overall. This results in efficiency gains being neutralised or drowned out by the number of devices sold.

If more than 9 billion people were to assume the manufacturing and consumption patterns of the industrialised world in the future, the international consequences for nature and the environment would be catastrophic.<sup>1</sup> Increasing resource productivity and decreasing the burden on nature and the environment in relative terms per commodity is therefore insufficient – the consumption of resources must diminish absolutely and thus be decoupled from economic growth.

To this end, the German Resource Efficiency Programme (ProgRess) adopted by the German government has formulated a central goal: to reduce the consumption of resources and the environmental pressures associated with it in order to secure prosperity and opportunities for development.<sup>2</sup> The programme follows the model of an economy embedded in material cycles. Improved technical measures in all areas of industrial production and measures that affect finished products should allow us to have an economy that conserves natural resources and, as far as possible, stops the environment from being contaminated in the long-term with substances that are damaging to both our health and the environment itself.

The concept of the circular economy is of utmost significance in this regard. In a circular economy, materials are used more sparingly and efficiently during production, products are designed and used in an environmentally friendly way, and waste is preferably prevented or – at the very least – subject to high quality recycling. This type of economy requires us to think in terms of what are known as material The German Resource Efficiency Programme (ProgRess) adopted by the German government has formulated a central goal: to reduce the consumption of resources and the environmental pressures associated with it in order to secure prosperity and opportunities for development.

flows, which take the entire lifecycle of raw materials and the products manufactured with them into account – starting with the mining of precious materials and rare earth elements for our mobile phones, for example, and going right through to the moment the products themselves are recycled.

Attention is hereby not only paid to the manufacturing and use phases occurring in Germany, but to the entire global value chain as a whole.

In order to use materials in a manner that conserves resources to the greatest possible extent, the materials contained in products must be kept within a material cycle as far as possible. At the same time, however, the accumulation of pollutants and contaminants must be avoided. A circular economy is thus successful when it succeeds in producing as little waste as possible that can no longer be used due to ecological concerns.

When the European Waste Framework Directive was implemented via the Circular Economy Act, a five-step waste hierarchy was introduced. In so doing, important guidelines were set regarding a focus on waste prevention, preparing waste for re-use, and recycling. Producer responsibility – concerning packaging or electrical and electronic devices, for example – also makes a contribution in this respect. This gives manufacturers the responsibility for ensuring that their products are recycled in a high quality, environmentally friendly way or disposed of in a manner that is commensurate with the public good after use.

#### First things first: preventing waste

The circular economy has been successful in Germany over the past few decades. Nevertheless, it still has a great deal of potential for further development. The annual total amount of waste generated has stagnated or even increased again slightly in recent years. There are various reasons for this. First of all, there exists a larger variety of products, innovation cycles are becoming shorter and shorter (particularly with regard to technical appliances), and fashion trends are changing with great frequency. This leads to people purchasing new products - such as electronic devices and textiles - with increasing rapidity. And just as in the past, every person in Germany still wastes around 81 kg of food per year (from the total 456 kg of food that is consumed at home).

#### The ecological rucksack of the food we eat

The food we eat comes with a significant ecological rucksack: cultivating and harvesting it, transporting it, purchasing it and disposing of it require water, energy and soil. The agricul-



The amount of food that each person buys per year in Germany requires the use of around a third of a football field of land, about 84 bathtubs of water, and causes 3 tonnes of greenhouse gas emissions tural land and water resources needed for the production of all foodstuffs are precious, scarce commodities across the globe. The amount of food that each person buys per year in Germany requires the use of around a third of a football field of land, about 84 bathtubs of water, and causes <sup>3</sup> tonnes of greenhouse gas emissions – equivalent to the amount of CO<sub>2</sub> produced by a flight from Frankfurt to New York and back. If we multiply these quantities to take Germany's 80 million inhabitants into account, the pressures on the environment are immense.

Anyone who buys food according to their needs and avoids creating waste is making a significant contribution to protecting the climate and the environment. The prevention of waste is more tangible with regard to the food we eat than in almost any other area of our lives. Food waste occurs at every stage of its production and consumption. Even during the first stage – the agricultural cultivation of foodstuffs – edible food is left out on the fields if it does not fulfil the usual commercial criteria regarding its shape, size and appearance, despite the fact that it is just as tasty and good to eat.

Significant amounts of food waste also arise during the "consumption phase", however. The waste balance of restaurants, canteens and event caterers does not look particularly healthy in this regard: a good third of the food prepared for what is known as "out-of-home consumption" is disposed of prematurely. 70.47 kg of food is kept ready for each person every year in restaurants, canteen kitchens or at events. Of this amount, 23.6 kg (or 33 percent) is thrown away before it is necessary. The reasons for this are numerous, and include the overgenerous calculation of the number of participants at an event, for instance, combined with a lack of incentives to plan more effectively as the food has already been paid for.

Fortunately, there are some positive approaches to dealing with this problem. One such strategy would be a voluntary commitment from the food retail and catering industries to reduce their food waste. These approaches are also mentioned in the German Government's Waste Prevention Programme with the participation of the German Federal States (Länder), and should be implemented as soon as possible. The legal and trading standards regarding the appearance and form of foodstuffs should be relaxed in particular. Furthermore, regulations that unnecessarily impede edible foodstuffs from being passed on should also be challenged.



## Please don't take this the wrong way: best before and expiry dates

One practical way to prevent food waste is to make sure that best before dates on such products as yoghurt and milk are not misinterpreted as "expiry dates". If milk does not smell bad or has not gone sour after the best before date has passed, it is entirely safe to drink. It is absolutely fine to trust your well-trained senses! Such easily perishable animal products as fish and meat that carry an expiry date should be thrown away when that date has passed, however.

Do not let yourself be taken in by special offers and (overly large) family packs – instead, plan your shopping in advance and do not buy too much. Correctly storing food in the fridge keeps it fresh for longer, and using up leftovers can become a real taste sensation with the right creative recipes. Many dishes may also still be warmed up again the next day or used for a new meal. Alternatively, you could always freeze your leftover food.

If you cannot eat food you have already bought yourself – perhaps because you are going on a spontaneous holiday, for example – you can give it to your friends, acquaintances or neighbours. This is made easier by such services as "food sharing" portals that allow you to receive and donate food. Food that has actually gone off belongs in the organic waste collection bin.

#### Modern products – environmentally responsible design

Product design is the key to reducing the environmental impacts that products cause over their entire lifecycle. Environmental protection-related design criteria should be enshrined as principles of equal rank to the practical, economical and legal requirements of the design process. Above all, product design must make use of approaches that increase the lifespan of products and make them easier to repair and recycle. The "Blue Angel" ecolabel and the German Federal Ecodesign Award are two important approaches to making environmentally friendly products more transparent for everyone, including consumers.

"The Blue Angel", Germany's best-known ecolabel, focuses on longevity and reparability in a number of product groups. For example, the Blue Angel is only awarded to printers when replacement parts are available for at least five years. The Blue Angel also sets standards for guarantees that go beyond the legal requirements for warranties. Furthermore, it stipulates that replacement parts be provided after a product has been taken off the market. This protects the environment, because every product that fails prematurely wastes both the energy required to manufacture it and a lot of raw materials. Consumers who buy products bearing



the Blue Angel are also protecting themselves against the need to make costly new purchases.

Since 2012, the German Federal Ecodesign Award – a competition for ecological product design – has honoured products, concepts and services that display the highest quality in terms of their design and ecological characteristics throughout the entire lifecycle of a product. In order to evaluate submissions, a criteria matrix was created that brings together all of the relevant environmental aspects of the design process over a product's entire lifespan. Aspects of waste prevention and of design that permits responsible disposal are also taken into consideration.3 In 2014, the prize winners included a recyclate initiative, which

won due to its innovative approach of using 20 to 40 percent old plastic (PET – polyethylene terephthalate) from the collection of separated recyclable waste in its packaging (bottles). Another prize winner was eSchrott, a free recycling search app that makes the disposal of electrical devices quick and easy by pointing its users in the direction of their nearest collection point.<sup>4</sup> Ecological knowledge about ecodesign must also be promoted in the education of designers, product developers and design engineers. Teaching modules for ecological design<sup>5</sup> should therefore support higher education in design and engineering with matters related to ecodesign. These are currently being tested out. Aspects of waste prevention and the circular economy will be included in the teaching materials.

Everyone should be able to change mobile phone batteries – not just experts with special tools Regulatory product design specifications are also needed alongside education and information, however, so that critical raw materials can be introduced into the cycle in a meaningful way. On an EU level, the Ecodesign Directive6 already serves to regulate energy-related products in general and electrical and electronic products in particular. A material-efficiency tool that examines aspects of product lifespan, recyclability, the recyclate content of synthetic materials, and raw material content shall be used in future. The first minimum requirements and/or information requirements regarding lifespan have been laid down in the executive orders on domestic lamps, vacuum cleaners and notebook computers. Requirements that would increase the recyclability of individual materials are being discussed with regard to televisions and other product groups. These requirements include the simple separability of components that are of particular relevance for recycling, and the labelling of certain substances and materials. Such approaches should continue to be rigorously developed in the future, not least because precious and special metals that are only used in trace amounts can often only be reclaimed when the flow of information between producers, manufacturers, consumers and waste disposal companies is optimised with regard to the recyclable material content of products.

The reparability of products is also an important approach to increasing their lifespan and encouraging their reuse.



#### The lifespan of electrical and electronic devices

"The Light Bulb Conspiracy"7: this documentary was one of the things that triggered a public and media debate in 2011 on the topic of "obsolescence" – the question of whether some manufacturers consciously build shortened lifespans into their products (known as built-in or planned obsolescence). The discussions on the topic had previously lacked statistical data above all, however. The German Environment Agency therefore carried out a study to examine the role that obsolescence plays in the wider context of the product lifespan and useful service life of a selection of electrical and electronic products. Based on the interim results8, trends of shorter first useful service lives and shorter life cycles can be seen in a range of products, but not in all of the products that were examined.

Large domestic appliances (fridges and freezers, cookers, washing machines, dishwashers, tumble driers) that were ultimately replaced due to a defect were used by their first user for 13.5 years in 2004. Their useful service life had reduced slightly to 12.5 years by 2012/13. Nearly a third of the large domestic appliances that were replaced were still functional, however. A critical point here is that the number of defective large domestic appliances that needed to be replaced after less than five years rose from 3.5 percent of all purchases in 2004 to 8.3 percent in 2012.

#### Figure 1

Percentage (%) of replaced large domestic appliances in terms of overall replacement purchases, classed according to reason for replacement and age group



2004: n= 2712; 2012: n= 5664 for large domestic appliances overall Source: Öko-Institut, University of Bonn: calculated using GfK data

In 2012, first users used flat screen televisions for 5.6 years on average before buying a new device. Only a quarter of these devices were replaced due to defects, however – over 60 percent of the replacement purchases in 2012 were made despite the old flat screen television still functioning. The average first useful service life of traditional CRT televisions overall fluctuated between 10.4 and 12.2 years from 2005 to 2012. They also lasted over ten years before they became defective (between 11.1 and 12.6 years).



#### Mobile phones, tablets, etc. – hotly desired then coolly ditched

#### Embarrassed by your old phone? Psychological obsolescence

The term "psychological obsolescence" has recently emerged in the debate surrounding the obsolescence of products. It refers to all kinds of non-technological obsolescence, i. e. cases in which products that are actually still fully functional cease to be attractive in the eyes of the user – either because new technological developments have emerged or simply because they no longer match up to the latest fashion trends.

This development has been encouraged by ever-shorter innovation cycles and marketing that suggests customers buy a new mobile phone every year. Incidentally, this kind of acceleration is particularly severe in the fashion industry, where "fast fashion" can result in up to twelve new collections being released onto the market every year. Sinking prices are also leading to products having ever-shorter useful service lives in the entertainment electronics sector. Seen from the perspective of waste prevention and resource conservation, these developments are extremely problematic. But how can they be combated?

#### | Longer useful service lives

Product developers are particularly crucial when it comes to extending useful service lives. Products that have a timeless design, that last a long time, and that are built using a modular construction are of critical importance. This kind of approach allows products to be updated with the very latest technology without replacing them completely. It also allows them to carry on being attractive. Incidentally, devices with a timeless design are also easier to sell.

As well as better engineering, there are also important initiatives that are working against the "throwaway mentality": there are now repair initiatives in many cities where people can repair defective devices together for little money. Exchange networks are also an important approach – they allow members to easily exchange products they no longer need with one another. These developments might only be individual examples, but they represent important steps away from the "throwaway society" and towards a culture in which repairing and exchanging goods is the norm.

#### Sharing, not owning: mine, yours, ours!

Low-waste lifestyles and patterns of consumption are a significant part of waste prevention and the circular economy. However, natural resources can only be conserved to a significant extent if environmental protection becomes a fixed part of people's everyday lives. A majority of citizens are aware that they can make an important contribution to the conservation of resources by leading a lifestyle that causes less waste. In order to do this, however, they must change their own consumption habits.9 Current figures on the sales of alternative "green" products10 and current trends in the furnishing of private households with consumer durables11 show that - despite some isolated positive developments – German people are only just in the early stages of implementing these changes in a practical way overall. In the most recent study, "Environmental Awareness in Germany 2014", 74 percent of respondents stated that they had already borrowed everyday items from friends and acquaintances. It makes particular sense to do this with everyday objects – such as drills and garden tools – that are often only used for a few minutes a year and otherwise

sit gathering dust in the cellar. In the survey, a growing number of citizens also stated that they had had positive experiences of buying second-hand goods or of making use of exchange, rental and sharing services.12

There seems to be a general trend for sharing including items ranging from people's own cars to their own apartments. The "sharing economy" and "collaborative consumption" have also gained in significance in Germany over the past few years.13 All of this revolves around the idea of "using, not owning" and new business models of needs-based consumption. Good examples of this from recent times include the public debate surrounding the expansion of services and web-based platforms for exchanging and sharing various consumer items (car sharing), and the increasing prevalence of a "resale culture"14 and a "maker culture"15 (e.g. repair initiatives, urban gardening). The spread of community-based models of sustainable living16 (e.g. ecovillages) is also an important element of the new patterns of consumption.

#### Figure 2:

#### Experience with and interest in professional sharing services



Source: BMUB/UBA (ed.): Umweltbewusstsein in Deutschland 2014 (Environmental Awareness in Germany 2014)

#### Figure 3:

Private households' level of equipment with consumer durables 2003-2011 IT sector, in percent



#### Figure 4:

Basic strategic model of a collaborative/sharing economy<sup>17</sup>



Sharing initiatives and experiments are also gaining increasing attention within the German government's environmental policy.18 The potential reduction of environmental impacts and further social and economic advantages (e.g. the integration of disadvantaged population groups; the market potential of new business and service models; and getting broader sections of the population involved in environmental politics) are particularly attractive. With its current projects under the Environmental Research Plan and the Verbändeförderung (promotion of associations), the German Environment Agency is supporting the systematic promotion of "using, not owning" models and social innovations for sustainable consumption.

#### **Unearth treasures from the past – Encourage re-use**

Reusing products or their components saves resources and avoids waste. An extended useful life contributes to conserving raw materials and reducing environmental impact through potentially lower production. The Recycling Law prioritises waste avoidance and the (preparation of) re-use that is thus perfectly proper for the "waste hierarchy". But how can one encourage this in practice?

#### Ein guter Trend: Reparatur-Initiativen

In the past few years, technical products have become more and more complex and too often repair-unfriendly. It can be heard therefore in an electrical store when an item malfunctions: It's not worth repairing – it's better to buy a new one right away. This is of course bad for the environment. It is particularly annoying if it is impossible to replace weak or damaged batteries or if it is complicated and only possible to do so with expert knowledge because they are mounted permanently in the device. However, there are opposing trends that have as a goal to breathe new life into defective devices that are presumed to be irrecoverable. Besides traditional repair services of specialist companies, there are repair-initiatives that are becoming ever more common (repair meetups, repair cafés, workshop cafés etc.) that organise temporary events. There's a simple principle behind the new trend: People meet at one place in order to repair together - and perhaps with professional support - their defective products. The participants there help each other out and share knowledge and experience on repair options and procedures. Participation at such events, which is often free of charge, can lead to products being repaired for which it is no longer worth paying to fix. There are now repair-café initiatives in over 13019 German cities, with more than 300 repair-initiatives networked nationwide20. The German Environment Agency supports such positive trends - through the promotion of associations. Moreover, the UBA develops strategies for the further dissemination of such "social innovations for sustainable consumption"21.

#### **Untapped potential: Repair centres rescue** electrical equipment

Much discarded waste electrical equipment goes into recycling. This is good for the environment, but it is even better for usable or easily repairable used equipment to be inspected, cleaned and after a minor repair, if necessary, to be used again. Although the law gives high priority to a "preparation for re-use", this happens only very seldom in Germany. A significant obstacle is that repair facilities nowadays hardly have access to end-of-life products, those collected at local recycling centres or with bulky waste - in particular waste electrical and electronic equipment. The German Environment Agency is searching for ways<sup>22</sup> to improve this. Thus, for example, appropriate waste electrical equipment should be separated already at the collection point and sent to repair centres. In order to increase consumer confidence in used equipment, quality requirements are specified furthermore for the repair facilities to salvage and resell such devices.

> Honey, it's working again!





### Nothing thrown away here – Examples for recycling

Waste that is neither avoidable nor reusable should be recycled – this is the third stage of the waste hierarchy. The goal of recycling is to reclaim the highest quality possible of secondary raw materials – for example steel from used washing machines or copper from used electric motors. Recycling helps with climate protection and reduces other environmental impacts. For some types of waste – such as iron and steel, copper, waste paper and waste glass – recycling in Germany is already long established and appreciated. However, there's a demand also here for further development – since pollutants can impair recycling. Current examples are mineral oil residues in recycled paper that come from printing inks or flame retardants such as hexabromocyclododecane (HBCD) in plastics that for example were used in television sets.

#### WASTE NOT, WANT NOT

#### Introduce more plastics into the cycle

Whether in the packaging, electronic or construction industry, the importance of plastics increases from year to year. Light materials such as plastics are a current trend, in particular for automobile manufacturing and in the wind energy sector. As a consequence, the amount of plastic waste also increases. In 2013 approximately 5.7 million tonnes<sup>23</sup> were produced. 41% of this was recovered mechanically and 57% energetically. A study of the German Environmental Agency that examined a potential increase of plastics recycling<sup>24</sup> has demonstrated that the amount of plastic waste that is fed into mechanical recycling can already be increased, for example by around 1.1 million tonnes through a stricter waste pre-treatment. This includes, for example, a strict separate collection of recyclable plastics, the optimisation of separation technology in sorting machines and above all a target of ambitious recycling quotas. An important step is the nationwide implementation of a standardised collection of recyclables in households ("recycling bin"). Mixed commercial municipal waste also offers an enormous potential for increasing plastics recycling. In order for recycling potentials as yet unexploited to be realised, further product

areas are placed in focus that could extend product responsibility, for example agricultural films or rotor blades for wind turbines.

## Plastic from end-of-life vehicles – As much as six times more can be recycled

Approximately 500,000 vehicles reach their end of life annually in Germany, with a total mass of around 500,000 tonnes. This contains about 15% plastics, or approximately 150 kg per end-of-life vehicle. In a typical scrapping however, only three to four kg of plastics are disassembled and re-used or recycled per endof-life vehicle in the form of large parts (for example bumpers).<sup>25</sup> The rest of the plastics remain in the body and are shredded with the other parts. In the shredders, approximately 70% of the vehicle's metal is separated and in this way recovered. From the remaining shredder residues, around 25% constitutes the so-called light-weight shredder fraction. This still consists of 40% from plastics<sup>26</sup> that are fed however predominantly into only inferior recovery paths.<sup>27</sup> Through an improved and deeper component dismantling before shredding, up to 24 kg of plastics could be recovered for recycling per end-of-life vehicle.



## Collect and recover precious and special metals

Whether in photovoltaic equipment, wind energy systems, electric vehicles or communications and information technology products: Many applications of these rapidly developing technologies are not able to do without precious and special metals. According to extrapolations in a study of the German Environmental Agency<sup>28</sup>, for example, the 30 types of electronic equipment sold in the year 2010 in Germany with the highest content of precious and special metals contained in total approximately 3.3-11 tonnes of gold, 20-54 tonnes of silver, 2.9-3.0 tonnes of indium, 630-910 tonnes of tin, 62-97 tonnes of neodymium, 200-460 tonnes of yttrium and 14–22 tonnes of tantalum. The most important product areas involved are PCs, laptops, mobile phones, digital cameras and television sets. The amount in German devices corresponds nevertheless to a proportion of several percent of the global deployment of precious and special metals in electronic equipment (among others, gold: 1.1-3.8%; neodymium 3.9-6.1%). In order to be able to recover these metals, new and adapted collection and logistics concepts are required, as well as new treatment processes for the end-of-life products in question. The smaller the end-of-life product, the more convenient the collection should be organised from the waste producer's perspective. Until now, small electrical equipment above all such as electric toothbrushes, hairdryers or mobile phones, end up in the grey bin, although this is not allowed. Bringing them to a recycling centre is simply too impractical because it is often too far away. This will change for waste electrical equipment as of summer 2016: Consumers can then return these devices much more easily directly in a store. This is provided in the amendment to the Electrical and

Electronic Equipment Act. By this combination of existing collection structures at recycling centres and the new collection points in stores, it is thus expected to become significantly easier for the consumers to return these items.

In order for the recycling of precious and special metals with typically very low concentration to accumulate a profitable mass, end-of-life products and waste with similar composition should be collected together if possible for recycling, for example various waste streams containing neodymium such as PCs and laptops (in hard disk magnets), loudspeakers, room air conditioners as well as wind turbines and electric bicycles (magnet in the electric motors). For resource conservation however, it is not only the precious metals in greatest economic demand that are crucial, but also the special metals. These include rare earths, gallium, indium or tantalum, for which recycling is not yet economically worthwhile because the extraction from ore, mining dumps and metallurgical by-products are (still) less expensive. The German Environment Agency will start a project within the scope of the Environmental Research Plan 2016 with the goal of developing measures that serve to better bundle and control waste streams containing precious and special metals. In this way, the total recycling chain shall be optimised with the aim of recovering resource-relevant metals. It is also important to improve the information situation of all participating players: If manufacturers also pass on the values content to consumers and waste disposal facilities, the collection as well as the recovery of precious and special metals will be improved through more specific collection and handling. And secondly, product designers learn as well if recyclers provide clear feedback on whether or not a product can be recycled easily.

#### Precious and special metals

Metals that are particularly corrosion-resistant, are called precious metals not just because of their high value. These include gold and silver as well as the platinum group metals. Differently from the bulk metals such as aluminium, iron and copper deployed in larger amounts, there are metals that are indeed used in much lower amounts in products, whose relative extraction costs and supply risk are however sometimes disproportionately higher. These are subsumed here under the term "special metals", for example indium, gallium, tantalum, tungsten, neodymium or cobalt.





#### Fertiliser from sewage sludge

Phosphorus is an essential nutrient for humans and animals and a key component of fertilisers in agriculture. Germany covers its demand for mineral phosphorus for fertilisers through imports. Through industry, for example through pesticides, metal treatment or rubber production, and human and animal excretions, a large portion of the phosphorus ends up in wastewater. Sewage treatment plants must then remove the phosphorus, so that the trophic level of waters is not negatively impacted by the outflow of sewage treatment plants. The phosphorus ends up by wastewater treatment in the sewage sludge. Because sewage sludge can contain a wide range of potentially harmful ingredients<sup>29</sup>, the German government wants to forbid the use of sewage sludge as fertiliser on fields. However, the fields don't obtain this phosphorus unless it is recovered from the sewage sludge<sup>30</sup>. The technology for this is available, even if not all on a large technical scale and at competitive prices. Essentially, two technologies compete: One method is the extraction of magnesium ammonium phosphate directly from the sewage sludge, which can then be used directly for fertilisation. A second method is the energetic recovery of the sewage sludge in monoincineration facilities. The phosphorus must then be recovered afterwards from the ash. The recovery rate lies between ten and 90% of the sewage plant intake and depends above all on technology costs. Many phosphorus recovery processes have already been tested successfully and must now be implemented on an industrial scale.

## New house from old house: Building rubble replaces natural gravel

On the order of 15 billion tonnes of materials are deposited in existing German buildings mostly brick and concrete.<sup>31</sup> Germany's building stock is in this sense an enormous source of raw materials. Yet from the approximately 53 million tonnes of building rubble that is 'produced' annually, only a mere fraction is exploited for high-quality uses. Natural gravel could thus be replaced, above all in building construction, if substitute material from building rubble is added to the concrete instead.<sup>32</sup> However, the majority of rocks recovered from building rubble are not used for high-quality utilisation in building construction (above ground), but simply as ballast in landscaping and road construction.

Because fewer people will live in Germany in the future in view of the demographic development - and the housing needs of the population are changing - there will be significantly higher amounts of building rubble in the future through the demolition and renovation of buildings. It is important that recycling aggregate quality is assured and that the structural properties of concrete from recycled materials correspond to that of primary concrete. This can be realised above all by a separate collection of debris during the actual demolition. It is also important to remove pollutants. Recycled concrete has many environmental benefits: it saves natural gravel, reduces land use and saves on long-range transport. It also meets the same structural requirements as primary concrete. Recycled concrete still has an image problem however - which could be confronted if the unequal treatment of recycled concrete is replaced by neutral quality criteria in public tenders. Up to 2020 one fourth of the requirements for gravel in concrete applications in the building construction could thus be replaced by recycling aggregates.<sup>33</sup>

Up to 2020 25% of the annual requirements for sand and gravel for building construction could come from recycled building rubble.

#### Pollutants from construction products

The recyclability of construction products is an important factor in the assessment of sustainability of buildings and so-called engineering structures (for example bridges and tunnels). According to the EU regulation for building products34/35, EU Member States may lay down binding provisions for the reusability or recycling of buildings or their parts after demolition. Besides the availability of suitable dismantling and recycling processes, knowledge about pollutants is important for the feasibility of these requirements (see Table) in future recycling. In order to prevent the spread and accumulation of substances that are harmful to the environment and to health in material cycles, the use of these potential contaminants is to be avoided in new construction products. A requirement for future harmless recycling is the labelling of potential contaminants in the product information. The German Environment Agency is committed to ensuring that the information necessary for the assessment of recyclability appear as a standard feature in the mandatory declaration of performance, therefore in the declaration by the manufacturer of a construction product in accordance with the EU Construction Products Regulation for the users and in the voluntary environmental declaration. The table below displays examples of substances of concern contained in construction products and also lists examples of harmless building products.

#### Table 1

#### Positive and negative examples of building product recycling from a materials perspective

Building product	Pollutants	Solution/ Proposal for improvement
Precast concrete element with aggre- gates from display glass (cathode ray tubes)	Heavy metals (lead, barium, strontium) <sup>36</sup>	Stop the use of display glass with ele- vated heavy metal content in construc- tion products
PVC-window from used-PVC-windows	Cadmium, lead	Maintain well-established separate collection and recycling
Fill from foam glass ballast as thermal insulation under foundation slabs manufactured from used flat-panel displays	Arsenic <sup>37</sup>	Use existing arsenic-free alternatives for the production of flat-panel displays
Artificial turf filling manufactured from scrap tyre granulate	Zinc, PAH (polycyclic aromatic hydrocarbons) <sup>38</sup>	Utilise harmless fillers
Wood-based materials from waste wood	None, if criteria of the Waste Wood Ordinance <sup>39</sup> are met	Strengthen demand
Bitumen for the production of asphalt from used bitumen roof sheeting	None (exception: root-proof sheets treated with mecoprop esters)	Encourage demand for recycling-bitu- men. Label sheets treated with meco- prop esters
Gypsum plasterboard manufactured from used gypsum plasterboards	None	Increase demand for gypsum from recycled material



## The leader of closed substance cycle management: Paper

Paper is recycled like practically no other product. Through processing in recycling, the fibres can be used up to seven times. In this way, the raw material is optimally exploited. A paper fibre is recycled in Europe 3.5 times on average.<sup>40</sup> Germany is a leader in Europe in paper recycling and contributes thus in an exemplary manner to this end to conserve resources and to close cycles. According to current statistics of the Verband der deutschen Papierfabriken (German Pulp and Paper Association)<sup>41</sup>, Germany's waste paper volume in 2014 amounted to 15.1 million tonnes, which corresponds to a high rate of return of approximately 74%, given a total paper consumption of 20.4 million tonnes. This includes the amount of waste paper collected by the waste paper business and the private and local waste disposal facilities. The waste paper utilisation rate also ran around 74%, with a waste paper proportion of 16.6 million tonnes to the total domestic paper production of 22.5 million tonnes in 2014.

As a general rule, heavily soiled paper fibres cannot be recycled for high-quality uses. One particular challenge exists if waste papers come in contact with non-recyclable waste, hospital waste or food waste, or the waste paper contains components that are difficult to separate such as oils or adhesives. These contaminants entering the paper cycle cannot be fully removed in further processing and can pose a public health risk. Thus the separate collection of waste paper and other waste streams becomes very important.

In order to avoid the accumulation of undesirable substances in waste paper from the cumulative recycling of paper fibres, it is always important to think about paper recycling also right at the product development stage, for example of printing inks or adhesives. If possible, only those substances should be used that do not impede recycling. It is important to promote relevant developments, for example mineral oil-free printing inks, environmentally friendly colour developers in thermal papers or removable adhesives. In this way and in the ideal case, downstream cleaning or protection can be dispensed with. Several companies have already undertaken print trials successfully with mineral-optimised inks. The results should be examined by publishing houses and the printing industry to see whether they can be implemented for press products throughout Europe.

## Recyclable banana peel: Bio-waste recycling

Bio-waste has already been collected separately since the eighties, in order for it to be used as fertiliser or as a provider of humus. Alone through bio-waste bins from households, nearly four million tonnes bio-waste were collected in 2012. There was no actual obligation for local authorities to collect bio-waste separately up to the commencement of the Closed Substance Cycle and Waste Management Act of 2012. This explains in part the wide span ranging from a comprehensive bio-waste collection in some states (Länder) to an almost non-existent one in others. In individual cities and counties, this means that between zero and 150 kg bio-waste is collected separately per resident per year.

With § 11 of the Closed Substance Cycle and Waste Management Act of 2012, the comprehensive implementation of separate collection of bio-waste became mandatory effective 1 January 2015. According to one study, the bio-waste bin has indeed been introduced comprehensively or at least in some areas in about 80 percent of the cities or counties; however, to date nearly half of all households in Germany are not equipped with a bio-waste bin. As reasons for the lack of bio-waste bins or other systems of separate collection, it is essentially the high costs for the separate collection of bio-waste that are mentioned by the cities and counties, often in connection with existing contractual obligations for waste disposal or particular waste treatment facilities. From the point of view of the German Environmental Agency, in order to effect an immediate and comprehensive implementation of the bio-waste bin, it is necessary in particular:

- to implement mandatory use of the bio-waste bin by the local authorities,
- to approve exemptions for the bio-waste bin in the local waste statutes only for documented expert self-composting and utilisation of the compost,
- and to prevent illegal disposal of bio and garden waste as well as burning it in one's own garden.<sup>42</sup>



#### Figure 6:

Total inventory of the anthropogenic deposit of the Federal Republic according to main 2,045 material groups in million tonnes

than one percent of the total materials deposit. The anthropogenic deposit consists of 26 billion tonnes of mineral materials, which is essentially loose rocks and sand, concrete and masonry blocks. It consists further of 1.2 billion tonnes metals, primarily steel, of 350 million tonnes of wood, of 250 million tonnes of plastics as well as 200 million tonnes of other materials.46

construction). Civil engineering, which com-

prises the traffic routes, drinking water and

wastewater infrastructure, energy as well as

information and communications networks,

building technology as well as in consumer and

capital goods is significantly smaller, with less

covers 44%. The deposit that is tied up in

The better the knowledge we have about these raw materials and the time frames for when these materials are again released from their stock, the sooner it will be possible to prepare for newly developed waste streams and their improved utilisation.

Mineral materials Metals Plastics Wood

## Other

The construction industry makes up the great-With a source stream policy to closed substance cycle est portion of the deposit. Alone 55 % of the amount of material is incorporated in residential and non-residential buildings (building

How great the contribution is to resource conservation through closed substance cycle management depends heavily on the type and level of quality of recovery. For the extraction, processing, refinement and electrolysis for one tonne of high-purity copper, approximately 128 tonnes of primary raw materials are taken from nature – among them copper ore, silica, limestone and crude oil. If on the other hand copper scrap is again processed to copper raw material, so that this can replace high-purity copper, only seven tonnes of new raw materials are required, in particular for energy sources for scrap collection, sorting, processing and melting. Ideally, by recycling one tonne of copper scrap, 121 tonnes of primary raw materials are thus saved. However, if copper goes into steel recycling as shredded recyclable material, the copper not only loses there its functional, physical properties but as contamination also reduces the quality of the electrical steel. Moreover, there is considerably less of an achieved effect for the substitution of primary raw materials for this so-called downcycling since the production of one tonne of blast furnace steel as reference product requires only 4.5 tonnes of primary raw materials.

management

In order to achieve the highest quality materials possible in waste recovery, a significantly better understanding of the material cycles is necessary as far as the use of material, its fate and behaviour in the stock and its re-release are concerned.

#### Waste statistics too imprecise

In order for the effects related to raw materials management and environmental protection of the recovery of secondary raw materials to be assessed effectively, waste statistics alone is not very suitable. It depicts, for household waste for example, only aggregate and in many cases very inhomogeneous source streams. Smaller but particularly valuable or environmentally relevant volume streams remain disregarded (e.g. rare earths and precious metals). Moreover, the statistics refer only to amounts of material that have attained waste status. In this respect, the quantities producible in this way ignore material cycles that do not affect waste legislation, for example through in-house or internal production recycling.

Backed up by studies however, reproducible and updatable source stream breakdowns are being developed increasingly. These are based firstly on an overview of recovery amounts and

estimates of recyclable material contents as well as secondly on sectoral and production-internal inputs and trading volumes of secondary raw materials.<sup>43</sup> By conveying materials and goods flows in individual source streams, they can usefully supplement waste statistics. The German Environment Agency promotes these developments because they provide new effective indicators for success monitoring and control for a source stream-based policy.

#### Mineral resources from the basement: Charting the anthropogenic deposit

A look at the total material flows of the German economy reveals: Germany is growing rapidly. A rough estimate of inputs and outputs during the past decades reveals for Germany an annual growth of the inventory of around 0.8 billion tonnes of material. The inflows from imports and domestically extracted raw materials into the so-called anthropogenic deposit (the totality of anthropogenic raw materials accumulated by humankind) surpass to a large extent the outflows from exports and emissions. In this way and in a half century - from 1960 to 2010 - around 42 billion tonnes of material have accumulated in the anthropogenic deposit. A study estimates the total inventory in Germany to be as high as 52 billion tonnes<sup>44</sup>, which corresponds to approximately the sum of all raw materials extracted world-wide in 2000<sup>45</sup>. The anthropogenic deposit is therefore a valuable secondary raw materials deposit - right at Germany's front door.

However, up to now we don't know the anthropogenic deposit well enough. Many of the materials that we find in municipal waste come from products with a short life of less than a year. This can be illustrated by taking the example of plastics (see Figure 5). In Germany, around 150 kg of plastics are processed per year and resident. Around one third thereof are found in short-life products such as packaging. Their share in the waste is proportionately high: Of the approximately 60 kg consumer plastic waste per year and resident, 60% is plastic packaging waste. Even if packaging plastics appear to be the most relevant for waste management, they have very little significance in the anthropogenic deposit, as plastics account for only roughly three tonnes per resident.

Relevant for the anthropogenic deposit are above all goods such as buildings, infrastructure, building technology as well as capital goods and consumer durables (see Figure 6).

**Proportion of packaging waste** 

Figure 5:

from plastic



Quelle: UBA

#### From material stocks to material flows

Material flows shift dynamically in the goods categories under consideration. For example, a relative high growth becomes apparent in civil engineering. Compared to the stocks, the utilisation of mineral materials in civil engineering is meanwhile about a factor of two greater than in building construction. Moreover, the amount of metal quantities deployed in civil engineering is also increasing. Much material is also necessary for the construction of new wind, biogas and photovoltaic systems. It is thereby interesting for a subsequent recovery that besides the bulk metals such as steel, aluminium and copper, relevant amounts of fibre-reinforced plastics and special and precious metals of strategic economic importance such as silver, tin, neodymium and gallium also become concentrated in these infrastructures.

Much of the burden we place on the environment in order to extract raw materials is not reflected in the market prices.

> How will the future waste volume change? In the long term there will be a shift from stock growth to a stock reduction - this means that material stocks again become material flows. We are already seeing trends for several goods categories where the waste streams increase significantly in relation to the newly introduced amounts of material. Reasons for this are in part that of a technical nature, such as lighter devices (for example flat-panel display vs. CRT monitor) or the miniaturisation of computers. Moreover, against the background of on-going internal migration and of the demographic decline of the population figures by 2050, it becomes apparent that in total throughout Germany a far greater amount of construction material, around one-and-a-half times, will flow out from the residential housing stock than will be newly brought into it.<sup>47</sup> In the long term, the building stock will thereby become a source of raw materials.

> The management of the anthropogenic deposit from long-life products, buildings, infrastructure ("urban mining") and deposits ("landfill mining") will therefore increase in importance. Besides the effectiveness and quality of the recovery, the amounts of material must also be managed. For this, evaluation schemes must be drawn up for urban mines, as well as a digital land registry and building and goods passes on which the raw material content can be read.

#### Conclusion

The recycling instruments derived from the waste hierarchy have already been applied successfully for decades – for example recycling – or were expanded – such as waste avoidance and re-use – under new auspices and insight, for example by sustainable product design and concepts to sustainable consumption. They help to further promote the paradigm shift from end-of-pipe waste management to a preventive closed substance cycle management.

In order to approach the long-term goal of closed material cycles, new concepts and instruments are to be established such as described above. A resource-conserving source stream management takes into account thereby also such effects of use of resources that occur abroad, for example in the extraction of raw materials.

We will need to increase the technical and logistic effort in order to exploit better still the raw material potential of our waste. Whether or not the benefits obtained warrant the costs involved should be assessed in the future less on current market prices and much more on how high the resource requirements and environmental impacts are that arise in order to produce comparable raw materials from primary raw materials. Much of the burden we place on the environment in order to extract primary raw materials is not reflected in the market prices of the raw materials. Materials that are extracted causing significant and in many cases escalating ecological impact and those incorporated in products by hi-tech manufacturing processes should also be recovered at the end of the utilisation chain by applying hi-tech processes in order to avoid repeated ecological burdens and to feed the materials back into the cycle.

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   Source: Instigation retrievable online at: http://
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56

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## Mobility of the future

The (energy) transition in the transport sector

The transport sector, especially road transport, is responsible for around 18 percent of German greenhouse gases – and is, unfortunately, the only area that has not been able to reduce its emissions since 1990. To change this situation, a large part of the traffic must be avoided in the first place and low-emission modes must become more widely implemented. In addition, we need a significantly more climate-friendly energy supply for the traffic.

Pages 60-79

## What is mobility?

**Transport performance in Germany, 2013** 1200 1100 **1151.0** bn pkm 1000 900 issenger transport in bn pkm 800 **645.0** bn tkm **欺** 700 729.7 bn pkm **돕** 600 400 300( 300.3 bn tkm oods traffic in bn tkm 200 1990 1995 2000 2005 Year

#### Infrastructure and freight volume in Germany, 2013



8.185 km Length of regional transport roads provided with cycle paths (federal, state, county roads)

#### E-mobility: clean only with solar, wind and water power









Use vehicles that are energy efficient and emit few pollutants.

Electromobility and electricity-based fuels Electricity from solar, wind and water enable the production of fuels that burn carbon-neutral.



![](_page_30_Picture_0.jpeg)

Car by pressing a button – car sharing replaces one's car, saves costs and the environment.

![](_page_30_Picture_2.jpeg)

## Still in the wrong direction: The transport volume grows

Mobility and accessibility are key preconditions for participating in society, economic exchange, employment and prosperity. Powerful and environmentally friendly transport systems are therefore essential. Transport, specifically transport performance1 has increased steadily in recent decades in Germany: Since 1960, passenger transport has quadrupled, goods transport more than tripled. For the future, goods transport in particular is forecast to undergo further increases. The reasons being the division of labour, production and logistics processes and the increasingly globalised trade interlacing2.

Even if the individual vehicles, whether car or lorry, have become significantly cleaner and quieter, motorised traffic still has many negative environmental impacts: greenhouse gases, air pollutants, noise, land-use and the consumption of raw materials such as steel and aluminium. With the increase in transport volume, energy consumption of transport in Germany between 1960 and 2000 has more than tripled. Currently, transport is responsible for at least 18 percent of greenhouse gas emissions in Germany. The main emitter is the energy industry with 39%. However, emissions in the transport sector have still increased compared to 1990 (by 0.6% by 2014). In many emerging countries (e.g. China), greenhouse gas emissions from transport have increased even more dramatically.

## Avoid, shift, improve – and find alternatives

In addition to the previously forecast reductions, in December 2014 the German Federal Government decided on its "Climate Action Programme" to reduce the emissions in the transport sector by another 7 to 10 million tonnes of  $CO_2$  equivalent by 2020. The European Commission also sees a need for action. In its White Paper Transport 3, it concludes that transport must overcome its dependence on fossil fuels and cannot continue to develop as in the past. These are positive signals. However, it is feared that these fall short of ensuring that transport contributes adequately to reducing global greenhouse gas emissions by 40-70% by 2050 compared to 2010.

A comprehensive strategy in the transport sector comprises four fields: firstly, avoidance of transport, secondly, shifting towards environmentally friendly means of transport such as rail and ship, thirdly, increasing energy efficiency and fourthly using post-fossil fuel, greenhouse-gas-neutral fuels and electricity produced from renewable energy sources. Transport services use alternative fuels and drive systems for reasons of resource- and cost-efficiency, but the energy needs of the entire sector must still be reduced – avoidance and shifting of transportation modes are therefore of particular importance.

## The right mix

Sustainable transport requires a mix of measures, since isolated measures alone do not achieve the required effect, while an integrated approach is often more effective. Also, improvements to the individual vehicle and its drive technology may not be enough. Even non-technical measures can achieve better climate protection. Economic incentives and payments, transport planning which aims to avoid traffic, and environmentally friendly modes of transport are all very necessary.

#### Environmental economic instruments – Taxes and Co.

Economic instruments can set financial incentives in order to promote an environmentally friendly transport behaviour. Energy taxation provides incentives to use fuel more sparingly in road transport and thus reduce emissions. This will motivate people to switch to fuel-efficient vehicles or public transport.

Different energy taxes are currently causing distortions in competition between transport modes. No energy tax is levied on aircraft fuel, while this tax has to be paid on petrol and diesel fuels. Even road fuel taxes show differences: energy tax on diesel is lower by about 18 cents per litre than on petrol. The German Environment Agency (UBA) recommends abolishing these environmentally harmful subsidies and raising the diesel tax rate to at least the level of

> Since 1960, passenger transport has quadrupled, goods transport more than tripled.

![](_page_31_Picture_0.jpeg)

Leider gar nicht super – Dieselfahrzeuge stoßen deutlich mehr Stickoxide aus als Benziner

the petrol tax rate. In turn, road tax on diesel cars should be lowered to that of petrol-powered cars. Since diesel fuel has a higher energy content than petrol – and higher specific  $CO_2$  emissions – a diesel tax rate above the petrol tax rate would even be appropriate.<sup>4</sup>

UBA takes the view that action is also needed to abolish other environmentally harmful subsidies such as the staff car privilege. Staff cars are company cars that are provided to employees which can also be used for private purposes. For private use, one percent per month of the vehicle's gross list price must be taxed through income tax as a cash benefit at the first registration. This tax regime favours staff car owners compared to private owners and is disincentive for climate protection since it is advantageous for employers and employees to have a part of the salary paid in the form of a staff car. UBA therefore recommends abolishing this privilege and restructuring taxation with differentiation according to CO<sub>2</sub> emissions.<sup>5</sup>

Attributing the external cost of transport, i.e. damage caused by noise or air pollutants to human health and the environment, is another important approach to reduce transport-related environmental stress. Until now, costs incurred in healthcare due to people falling ill with asthma due to contaminated air, has only been attributed in general and not specifically to the source of environmental pollution, i.e. transport. This cost is simple to attribute according to the polluter pays principle: goods transport cost can be internalised, for example, by increasing and expanding the heavy vehicle toll. UBA recommends extending the toll to all lorries and buses of gross vehicle weight of 3.5 tonnes and above to all road categories. Toll rates should be specified so that they reflect the entire environmental cost.6

#### Stadt und Region der kurzen Wege

Where we live, work and shop determines to a large extent how far apart our daily goals are. Everyday short distance journeys in a city and region can be made within a short time without a car. What is needed is a compact city structure, an environmentally compatible mix of uses and an attractive pattern of the residential environment and public spaces - for example by traffic calming and parking management. Short distances can be travelled healthily by bicycle or on foot. This reduces the traffic volume and complements a well-functioning ecomobility in local transport by bus and train. If routes are shorter, less land and resources are used and exposure to noise and air pollution also decreases. Many municipalities have been aiming at the mission of "short distances" for years. The "Guiding concept city and region of short distances" project funded by UBA shows how the Federal Government can support local communities. This project was organised within the Biodiversity Strategy to reach the land protection objective of "30 hectares per day by 2020".7

The Federal Government wants to limit the increase of land-take from currently more than 74 hectares (ha) per day to 30 ha per day by 2020. Of this, about 24 ha will go to residential areas and approximately 6 ha to transport routes. The "Saving Land Action Plan" instigated by UBA provides appropriate and practicable instruments for this purpose.8 In addition, UBA, together with around 100 municipalities, will investigate if trading land certificates is an effective and applicable instrument for municipal practice in a nationwide pilot project.

![](_page_31_Picture_8.jpeg)

#### CO, limits to speed limit

In order to achieve specific environmental objectives of transport policy, regulatory instruments such as orders and prohibitions are preferably applied in transport policy. Vehicle-related emission standards are an example. UBA welcomes the introduction of emission class "Euro 6" with more stringent nitrogen and carbon black limits for all new car models since 01.09.2014. The future challenges of exhaust emission legislation are that future vehicles for normal-use have better emissions reduction and vehicle fleet emissions are more strongly taken into account. The RDE process (real driving emissions), currently running in the EU, aims to significantly reduce existing major deviations of NO, emissions in actual operation from the limiting value of type approval and make an important contribution to air pollution control. After completing the process, measurement of vehicles in real traffic – and no longer only on a laboratory test rig - will be compulsory for the type approval of new vehicles.

In recent years, CO<sub>2</sub> emissions of newly registered cars have significantly decreased in the test cycle - probably also due to the CO, fleet targets that have been binding for the manufacturer from 2012. The emissions target, in force from 2021, envisages 95 grams for the average CO<sub>2</sub> emissions of all newly registered cars in the EU. It is necessary from a climate protection point of view to further lower this target after 2021. UBA recommends further reducing the emissions target of 95 grams by 15 to 25 percent and compulsorily stipulating it by 2025. What applies to cars, should also be introduced for lorries, ships and aircraft; regulatory instruments similar to the "technology-neutral fleet targets for cars" should also be introduced for these transport modes.

Speed limits are another example. Fuel consumption of vehicles increases disproportionately at high speed, thus a speed limit primarily has an effect on motorways and main roads. Also for reasons of transport safety and noise protection, for a long time UBA has recommended a speed limit of 120 km/h on motorways, 80 km/h on main roads and a control speed of 30 km/h in urban areas. A speed limit does not cost anything and works immediately. In addition, permanent speed limits entail

> UBA recommends expanding the toll to all lorries and buses from a gross vehicle weight of 3.5 tonnes and to all roads.

significant additional savings potential: since the high top speeds of today's vehicles can then no longer be exploited, the vehicles would have less powerful engines and weigh less so would lower consumption even more.

Meanwhile, there are 50 environmental zones in Germany (as of mid-2015), the first of which was introduced in 2008.9, 10 Analyses of the cities and municipalities with low-emission zones show that air quality has improved in the city centres. Low-emission zones are thus an important tool to protect people in cities and conurbations against particulate matter and other air pollutants detrimental to health. To further improve air quality, the environmental zone must be further developed. Today over 90 percent of the cars receive a green sticker based on the Labelling Provision adopted in 2006. Nitrogen oxides are increasingly the main problem of air quality in city centres. Around 60 percent of measuring stations near road traffic in metropolitan areas exceeded the annual average limiting value for nitrogen dioxide in 2014, the main reason being NO<sub>2</sub> emissions from road transport and in particular from diesel vehicles.

In addition to the existing red, yellow and green stickers, another environmental sticker should be introduced to identify vehicles with particularly low NO<sub>x</sub> emissions. The new sticker would allow municipalities to provide better

air through access restrictions. UBA appeals for extending the environmental zones on building machinery, diesel locomotives and inland waterway vessels over the medium term; they may cause a significant proportion of particulate pollution in certain cities and regions.

## Accompanying measures: making cycling and walking more attractive

Those travelling on foot or by bike, protect their health and the environment and make a substantial contribution to transport transition in Germany.11, 12 To facilitate the transition from car to bicycle, pedelec13 or cargo bike, the cycling infrastructure in Germany must be better. In many places it lacks bicycle superhighways and well-maintained high-quality bike paths, especially in the municipalities where there is a high demand. Tax and legal incentives can also help, for example, parking space requirement for bicycles near houses and flats to make cycling more attractive.

While the bicycle share fortunately slowly increases, little planning attention is currently being assigned to pedestrian traffic. Compact settlement structures, mixed use, plenty of short-cuts and clear routing without detours can ensure short distance usage which is essential. UBA recommends developing a "Pedestrian strategy for Germany" to enhance this basic type of mobility.

![](_page_32_Picture_9.jpeg)

The German rail network must be systematically expanded and upgraded to ensure a greater shift of goods transport towards rail as required by the EU White Paper on Transport. In the short term an optimised instrumentation and control system, an increase in the number of signal blocks or speed harmonisation and smaller infrastructure measures such as the construction of passing sidings or junction curves can significantly increase network capacity. In the medium term over 700 kilometres of track must be newly built and over 800 kilometres of track should be electrified to allow a doubling of rail transport by 2030. This requires funds amounting to around 11 billion euros.17 Money invested here would be well spent as the external environmental cost caused by one tonne of goods per kilometre on the road (diesel lorry) is about nine times as high as on the railway (electric goods train).18

![](_page_32_Picture_11.jpeg)

#### Around 60 percent of measuring stations near road traffic in metropolitan areas exceeded the annual average limiting value for nitrogen dioxide in 2014. The main reasons are $NO_x$ emissions from road transport, in particular from diesel vehicles.

![](_page_32_Picture_13.jpeg)

## Getting ahead with less energy – improving technical efficiency

It applies generally: improved technical efficiency can save energy, avoid environmentally harmful  $\rm CO_2$  emissions and therefore protect the climate<sup>19, 20</sup>. However, different potentials can be observed for each mode of transport – and therefore there is a distinctive need for action.

UBA envisages a very high potential for reducing the specific energy consumption of cars and light utility vehicles over the long term: up to 50 percent for conventional drives such as petrol and diesel. Partial electrification of vehicles, employment of high-efficiency drives and consistent vehicular weight reduction are the key options. The state can promote the technological development by extensively exploiting CO<sub>2</sub> legislation. It is important that a comprehensive regulation of energy consumption in new registrations is finally carried out under actual driving conditions (see also "Concept for future evaluation of car efficiency"<sup>21</sup> commissioned by UBA).

Road goods transport will continue to increase strongly in the future. From a climate protection point of view, therefore, the efficiency of heavy-duty vehicles must be improved both in time and practicality. UBA commissioned the "Future measures to save fuel and reduce greenhouse gas emissions in heavy duty vehicles" project to systematically investigate the potential of fuel consumption and greenhouse gas emission reduction by selected technologies in the power train, improving aerodynamics and rolling resistance as well as optimising vehicle weight, secondary consumers and vehicle regulation.<sup>22</sup> Project also included cost calculations for long- and short-haul lorries and buses.

Fuel reduction in air transport is currently not enough to compensate for the strong global

![](_page_33_Picture_7.jpeg)

International maritime transport contributed about 2% to global CO, emissions in 2012 and the annual growth rates for this sector are estimated at 2 to 3%. The International Maritime Organization (IMO) assumes that CO<sub>2</sub> emissions from navigation may rise by 50 to 250% by 2050. Technical and operational measures such as slow steaming (intentional speed reduction for ships to save fuel) can provide a large energy saving and efficiency potential. This potential can be efficiently implemented through market-based measures such as an emissions trading system. Therefore, the EU adopted a Monitoring Regulation ((EU) 2015/757) as preparation in 2015, and the IMO is currently developing an international CO<sub>2</sub> monitoring system. These measures are being analysed and further concepts and options developed in the ongoing UBA project "Climate protection and maritime navigation" to improve the sector's carbon footprint.

Environmental damage caused by one tonne of goods per kilometre transported by a diesel lorry is about nine times as high as that by an electric goods train.

![](_page_33_Picture_10.jpeg)

#### Climate-friendly alternatives: new drives and fuels

The transport sector needs environmentally compatible energy supply to meet the global climate protection targets. From today's perspective, the pure in-use phase of vehicles where fuels are provided and used, plays the most important role for the carbon footprint of transport. It causes in average of more than 80% of greenhouse gas emissions for all modes of transport. Production, marketing, delivery, maintenance and recycling or disposal of vehicles, aircraft and ships account for only 20%.

Alternative drives and renewable fuels can virtually ensure a greenhouse-gas-neutral energy supply for the entire transport sector, including aviation and shipping.<sup>24</sup> Electricity generated renewably can either be used directly in vehicles with an electric motor or indirectly by forming the basis of electrically generated gaseous and liquid fuels.<sup>24, 25</sup> This may enable transport to increasingly dispense with conventional fuels produced from fossil base materials. Accordingly, the transport industry must be considered as a new additional consumer when expanding or setting targets for the development of renewable energy in the electricity system. Simultaneously, new power consumers in the transport industry such as electric vehicles

will help integrate the fluctuating wind, water and solar energy into the energy system. The climate-friendly supply of transport is thus an important part of the restructuring of our entire energy system towards a greenhouse-gas-neutral supply.<sup>26</sup>

#### **Electric drives and alternative fuels**

Currently, most transport modes use liquid fuels of fossil origin<sup>27</sup>; electricity is currently rarely used for transport energy supply such as in rail transport.

#### Electromobility

Electric drives are, in combination with storage batteries, overhead lines or fuel cells, technically feasible and are currently being intensively discussed under the heading "electromobility" and promoted by the policy. 1 million electric cars should be running on German roads by 2020 and save 0.7m tonnes of  $CO_2$  in transport.

In addition to battery-powered electric motors, a power supply using power conductors is also possible – as in trams and trolleybuses. Direct

![](_page_33_Picture_20.jpeg)

electric drive converts electrical energy in motors directly and very efficiently into vehicle movement without further conversion steps. Electric vehicles have the advantage that they do not emit greenhouse gases during operation and - aside from abrasion of tyres and brakes nor air pollutants. Thus, they create a very efficient way of ensuring better air in city centres. The greenhouse gases and pollutants, however, are created elsewhere; at the point where electricity is generated for electric vehicles from fossil fuel in power stations. Therefore, it is important to convert the energy system so it can generate 100 percent of power in the future centred on renewable energies. Then – except for the use of bioenergy – these emissions will also be eliminated to a greater extent.

Electric vehicles either need batteries in the vehicle along with a charging infrastructure or must be fed from an overhead power line. Production of the vehicles, and in particular, the large and heavy batteries, is more energy and resource intensive than that of conventional vehicles. This is currently reflected in the high production cost and greater environmental impacts. Besides, battery storage is accompanied by charge and discharge losses. In addition to low local emissions, the main drivers for the development of battery electric vehicles are, in particular, the falling cost and the technical development of batteries.27 Battery electric vehicles are currently promoted by the Federal Government with the aim of having one million vehicles on the streets by 2020.28 The European CO<sub>2</sub> fleet limit for new cars can be considered as a measure to promote electromobility. In this context it must be noted that currently, only direct CO<sub>2</sub> emissions per kilometre are taken into account for the car fleet target. This makes electric vehicles better off compared to diesel or petrol engines because they do not emit greenhouse gases during operation. However, this can lead to more emissions based on the entire vehicle fleet. Although the fleet average of 95 grams of CO, per kilometre as from 2021 will be achieved, it is likely that the electricity supply will produce additional emissions of a few grams of CO<sub>2</sub>. Therefore, the

additional electricity for electric vehicles must

be produced renewably in the future.

![](_page_34_Picture_5.jpeg)

![](_page_34_Picture_6.jpeg)

#### Greenhouse gas emissions and efficiency in diesel and electric vehicles

Greenhouse gas emissions of an electric and a diesel vehicle are shown in Figure 1 broken down into the supply and use phase. When using electricity generated renewably, electric vehicles achieve significant climate advantages compared to vehicles with an internal combustion engine. However, if the power is generated from fossil fuels, this does not lead to a climate advantage. In this case, energy conversion efficiency over the overall path for the electric vehicle is no better than for a diesel vehicle. The reason is primarily conversion losses in power generation from fossil fuel. But unlike electric vehicles, diesel vehicles emit harmful emissions such as nitrogen oxides or small amounts of particulate matter during operation.

A substantial portion of power supply is currently based on coal and natural gas so that an increase in conventional electricity consumption by electric vehicles will lead to higher greenhouse gas emissions. Since an increasing share of renewable energy can be expected in the future electricity mix, this alone will enhance climate compatibility.

![](_page_34_Figure_10.jpeg)

Figure 1: Greenhouse gas emissions (kg  $CO_2$  equivalent) in the supply and use phase for an electric vehicle (electricity) and a diesel vehicle (diesel) along a driving distance of 100 km. Two possible paths and the 2012 electricity mix are shown for electricity supply by way of example. Estimated coal efficiencies are indicated for the vehicles' use phase and the coal-electricity conversion. Unlike electric vehicles, in addition to the greenhouse gases, diesel vehicles also emit air pollutants during their operation. [Authors' calculations and fuel consumption based on <sup>29</sup>].

## Battery electric vehicles: hybrid, with range extender or purely electrical

Hybrid vehicles have an electric motor and an additional engine – typically an internal combustion engine – powered by diesel or petrol. They are also available with external charging facilities (so-called plug-in hybrids) to utilise energy from the power grid. Electric vehicles with a range extender have, in addition to the electric motor, a (small) internal combustion engine. This is not used for driving, it only produces electricity via a generator for the electric motor if the battery is empty and there is no charging facility nearby. Finally, there are also pure battery electric vehicles with power storage and only external electricity charging possible.

From today's perspective it seems realistic that battery electric cars will be competitive in the medium term for the short- and medium-distance transport when their cost can be reduced and the vehicles have established themselves. Partial or complete electrification is in principle also conceivable for bus transport in metropolitan areas and lorry delivery in the medium to long term. The construction of a charging infrastructure may be a problem as it will be unlikely to refinance itself especially in the early years because of the small number of users. The structure itself is pushed by the EU Directive 2014/94/EU with mandatory minimum numbers of charging points.

It is important to consider the entire life cycle in a comparative assessment of the environmental impact of vehicles with internal combustion engines and battery-electric drive. Figure 2 shows some aspects of such an assessment from a study currently commissioned by UBA31. The results show that the production of electric vehicles is accompanied by higher greenhouse gas emissions than that of conventional vehicles both today and in the future. However, if it is assumed that electric vehicles will be supplied with 100% renewable electricity in the future (Figure 2), the electric drive has clear environmental advantages over petrol and diesel engines. In this case, the emissions from electricity production (green in Figure 2) are almost zero, and the higher emissions of vehicle manufacture are more than compensated. Although the environmental effects were not taken into account by the extra charging infrastructure required in the study, the climate advantage of electric drives would remain even so.

#### Infobox: electric cars - interactions with the power system

Electric vehicles are new electricity consumers and must be taken into account along with the targets of renewable energy expansion. At the same time electric vehicles can schedule the charging time for cheap periods in the power structure, as is the case by night when the power demand is low and a lot of wind power is fed into the grid. In the long term it is also conceivable that when batteries have better durability, electric vehicles could provide network services through an intermediate electricity storage, that is, they feed electricity back into the grid when needed. All this can be useful for the integration of renewable energy into the existing energy system.

If electric vehicles are more widely used, there will be a shift in energy consumption in the European emissions trading system that has so far barely covered transport. The future framework for emissions trading can and should take into account an increasing electromobility. A cross-sectoral coordination of the reduction targets is needed so that electromobility can make a real contribution to climate protection

## Electric vehicles need a lot of raw materials – some of which are rare

Although electric vehicles do not have a tank, they need batteries to store energy. Compared to a car with a petrol engine, a plug-in hybrid needs about 60% more raw material for its manufacture, a pure electric vehicle even up to 90% more than a petrol engine.<sup>31</sup> Cobalt, some rare earth metals and nickel are some special materials that are needed. Some of these metals are already critical because of scarce resources. Recycling of the electrical components and the vehicle batteries is important in order to close the material cycles, thereby reducing the environmental impact of vehicle manufacture.31

Calculated over the life cycle, both plug-in hybrids and battery-electric vehicles today show some ecological disadvantages (for example, in terms of particulate matter and water balance) due to the production of batteries and electrical components compared to conventional drives. Electric vehicles, however, are already at an advantage concerning summer smog, ground-level ozone and land eutrophication because carbon monoxide, hydrocarbons and nitrogen oxides emissions while using internal combustion engines are greater than even in the current mix of power generation. Technical progress is proceeding however, thus energy density per battery will rise and the resource use of electric vehicles will considerably decrease by 2030. In addition, by closing the recycling cycles, the demand for primary raw materials will decline. This will enable the current ecological disadvantages to be drastically reduced in the future, or

Electric vehicles need about 60% to 90% more raw material for their manufacture than petrol engines. Cobalt, some rare earth metals and nickel are needed among others.

gCO2equivalent 250 200 150 100 50 Plug-in-Plug-in-Petrol Diesel Electric Petrol Diesel Elektro hybrid engine engine vehicle engine engine hvbrid farzeug 2030 Today Electricity provision, mix Fuel utilisation/ Fuel provision Electricity provision, RE exhaust emissions Vehicle manufacture, maintenance (example of wind power) and disposal

## Life cycle analysis of various compact vehicle concepts<sup>30</sup> by the example of the climate impact in gCO<sub>2</sub>equivalents per km travelled. [Authors' illustration based on <sup>30</sup>]

conversely, their conversion into environmental benefits. As far as the subject of acidification is concerned for example, electromobility will have a positive balance in the future. Taking into account the entire life cycle, electromobility will achieve an enhanced environmental performance much faster when renewable electricity is used consistently.

Overhead conductor line electrical drives can be useful on the road, not just on rails and in particular when batteries cannot be, or are difficult to use. Batteries are in particular questionable in heavy-duty vehicles such as lorries and buses, therefore a power supply via overhead conductors would be a good alternative. Electric buses with overhead conductor pickups are ready for the market and have been successfully used in urban transport in other countries (e.g.

70

Figure 1:

350

300

![](_page_36_Picture_2.jpeg)

Overhead conductor lorries on a test section

in Switzerland) for decades. Currently, overhead conductor long-haul lorries are being discussed in Germany. Their high energy efficiency speaks for overhead conductor systems because there are few conversions between various forms of energy and the electric motor is highly efficient. However, expenses accompany this approach: the overhead conductor infrastructure required would have to be built because roads are not electrified and the vehicle fleet would also have to be changed. High-capacity exploitation is needed over the medium and long term to make the construction of infrastructure rentable. A particularly efficient system would require the development of cross-border systems. Because of these barriers, UBA banks on the shift of goods transport towards a mode of transport already electrified: e.g. rail.

Fuel cell vehicles represent another alternative within the sphere of electric vehicles, but they have not yet reached market maturity. They are locally also almost free of emissions. Their advantages over battery electric vehicles are their higher range and faster refuelling. However, their energy consumption is significantly higher – because of the twofold conversion (electricity hydrogen – electricity). Besides, the vehicles are now very expensive.

## Other options: hydrogen, methane and natural gas

Alternative fuels such as hydrogen, natural gas and methane are currently used only in niches. Hydrogen can be used in electric vehicle fuel cells of but also in internal combustion engines. The direct emissions from combustion do not pollute the air, however, hydrogen production from fossil natural gas may cause significant greenhouse gas emissions. An infrastructure for hydrogen supply is so far only sporadically available, further expansion is costly.

Natural gas or methane can be used in internal combustion engines and aircraft jet engines. Due to the carbon to hydrogen ratio, which is favourable from a climate perspective, around 25 percent less greenhouse gases are emitted directly compared to diesel or petrol per unit of energy.<sup>32</sup> Currently there are efforts to establish liquefied natural gas as an alternative fuel in international maritime shipping. This in particular aims to significantly reduce the emission of nitrogen oxides and sulphur dioxide. But it is important to consider the provision of fuels. There are large differences, including synthetic methane, based on renewables (see next section). For natural gas, there is a well-developed infrastructure in Germany.

## Alternative fuels: post fossil and greenhouse gas neutral

Transport is currently being powered almost entirely by fossil mineral oils. Natural-gas-based products are represented in the fuel market to a far lesser extent. The transport sector must be able to do without fossil fuels but needs viable alternatives in order to become carbon neutral. And they are there: in particular, the direct use of renewable electricity as well as its indirect use is already here.

## Biodiesel and Co.: biofuels are scarce and involve high risks

Biofuels can be produced from various biomass resources. Primarily, biomass specially grown is being used so far. However, intensive research is being performed on ways to efficiently use the large number of different residues and wastes of vegetable or animal origin. Technical discussions distinguish between the terms biofuels of the 1st and 2nd generation, sometimes exclusively according to the origin of raw materials used, sometimes simply according to the historical order of market maturity of the technical processing possibilities. The environmental impacts of biofuel production can vary greatly - especially on a global scale - depending on the raw material, processing method and quantity used. Agricultural production of raw materials (of 1st generation, e.g. rapeseed, oil palm, corn or sugar cane) has much larger potentially negative environmental impacts according to estimates than those caused by the collection of residual materials (e.g. used vegetable oil, straw, corn cobs) or wastes (e.g. biogenic portion of municipal waste, slaughterhouse waste, garden rubbish and landscaping waste).33

The environmental and social impacts of using specifically grown biomass are complex and largely intertwined. Thus, the amount of plants grown for human consumption that have been removed from the food market into biofuel production, must often be replanted in a different place to meet the rising global demand for food. The increasing competition between different sectors of biomass use (food, material use and energy) for cropland and pasture contributes internationally among others to displacing existing crop patterns, expansion of agricultural land or even to an abrupt intensification of increasing the area yield. An increasing demand for cultivated biomass to produce biofuels also to a significant extent exacerbates the growing problems of global land use such as deforestation, ploughing up of grassland, soil degradation, high water consumption and water pollution, loss of biodiversity, and others.

Since early 2011, sustainability criteria have applied to biofuels, which relate to minimum standards in climate protection and protection of ecologically valuable land. Biofuels must exhibit a greenhouse gas reduction potential of at least 35 percent compared to fossil fuels. The greenhouse gas reduction of biofuels depends very much on the individual case (biomass used, production processes, logistics, use of co-products etc.). These criteria must be met worldwide, even if the biofuel or biomass were produced outside the European Union. Evidence that the sustainability criteria are met regardless of the country of origin must be provided in the Federal Republic of Germany and in the European Union by means of private-law certification systems and bodies.

Agricultural production of raw materials has much larger potentially negative environmental impacts than those caused by the use of residual or wastes

![](_page_36_Picture_16.jpeg)

A globally observed increase in demand for agricultural products is due to various reasons. Changing food preferences in the so-called emerging and developing countries have a strong influence on land use and the population is increasing. The demand for milk and meat products gradually approaches the industrialised countries own very high levels. A politically motivated promotion of biofuels (e.g. purchase guarantee) caused another increase in demand within a relatively short period in those countries or regions of the world that have a great influence on the agricultural markets (especially US and EU). A sharp rise in oil prices, poor harvests, empty stockpiles and increasing demand led to very volatile and at times rapidly increasing global food prices in 2008. This caused a serious decline in food security for poorer population groups, particularly in growing cities of the global South, sometimes accompanied by a further worsening of the general security situation. Increasing demand displaces existing land uses (e.g. extensive animal husbandry and subsistence farming) in rural development. In addition to the ecological problems, an abrupt intensification of production to provide additional biomass- can cause or exacerbate complex social and economic problems. An extensive transition to raw material cultivation for biofuel production and accompanying changes in agricultural structures (monocultures, heavy dependence on expensive fertilisers and pesticides) can restrict food supply regionally and locally, and imported food may cause prices to skyrocket. Small farmers who do not have the funds and knowledge needed for the transition to the new and very intensive farming practices, increasingly lose their livelihoods and are directly or indirectly expelled from their land. Many migrate to the cities where they become vulnerable to volatile food prices or try their luck by clearing a piece of forest in order to gain new farmland.

These complex dynamics have been critically discussed for some time concerning the role of biofuels in climate change. Land-use changes such as wood clearing or the ploughing up of grassland for expansion of agricultural land

have immense greenhouse gas emissions that are proportionately attributable to biofuel production. The extent of these emissions, often caused indirectly, however, is very difficult to determine due to the globally intertwined processes. Nonetheless, where this has been attempted by means of econometric models, alarming actual greenhouse gas emission figures due to biofuels were obtained, which raised significant doubt about their fundamental climate protection effect. According to the precautionary principle, the EU Commission has responded to the above risks with a proposal to limit the amount of such support-eligible biofuels that are produced based on food crops or crops specially grown for this purpose. A corresponding provision for limiting the energy content of such fuels to 7% of the EU Member States' transport sector energy consumption at an agreed target of 10% renewable energy - entered into force in 2015 and is welcomed by UBA.

In addition, biomass cultivation needs significantly greater areas compared with photovoltaic or wind energy in terms of the same amount of energy yield per square metre cultivation/ panel area (see Figure 3). UBA therefore recommends that biomass should be used for energy production, if at all, and then only relying on residues and wastes such as used vegetable oil, straw, biogenic portion of municipal waste and slaughterhouse waste. This also means that biomass can only serve niche markets at best. UBA considers cultivated biomass crops, i.e. plants that are specifically grown for energy production purposes, not even a temporary solution by virtue of such risks, because the damage caused may affect later generations.

#### Figure 2:

Characteristic per-area renewable energy yields and their bandwidths for two typical radiation volumes under conditions appropriate to Germany<sup>34</sup>

[authors' illustration according to <sup>35</sup>].

![](_page_37_Figure_9.jpeg)

![](_page_37_Picture_10.jpeg)

Biomass needs significantly larger areas compared to photovoltaics to produce the same amount of energy.

One must advocate alternatives for fossil fuels in order to make the transport sector carbon neutral.

![](_page_37_Picture_13.jpeg)

#### WHAT MATTERS 2015

#### MOBILITY OF THE FUTURE

#### **Power – fine if generated renewably!**

If we expect our future cars and buses to be powered by electricity, then direct electricity use is certainly an obvious option – either using batteries or overhead conductors e.g. trains. Gaseous or liquid fuels produced from electricity represent another option. The process – increasingly known under the buzzwords 'power to gas' (PtG) and 'power to liquid' (PtL) – constitutes another option for transportation. In this technology, electricity is generated by renewable energy (wind, water and solar) for electrolysis, which splits water ( $H_2O$ ) into hydrogen ( $H_2$ ) and oxygen ( $O_2$ ). Hydrogen can be used directly as an alternative fuel. If carbon dioxide ( $CO_2$ ) or carbon monoxide (CO) is added, the gaseous fuel methane (CH<sub>4</sub>) can be generated in a catalytic synthesis (also called methanation) from hydrogen. Also, a hydrogen-carbon monoxide mixture can be converted into liquid hydrocarbons using the Fischer-Tropsch process which was developed in the mid-1920s. These longchain hydrocarbons produced in different ways can be processed and fractionated and used as diesel, petrol or kerosene variants. This means that crude oil, the main source of these fuels, can be replaced with environmentally friendly alternatives. Energy yield is highest when hydrogen is used directly; efficiency significantly decreases however, from methane down to liquid fuels.

#### Figure 3:

Simplified 'power to gas' and 'power to liquid' process [authors' illustration according to <sup>36</sup>].

![](_page_38_Figure_7.jpeg)

Direct electricity use is usually the cheapest and most environmentally friendly option due to high conversion losses and investment costs in the PtG and PtL processes. Therefore, direct electric use should be preferred, all the more in that it is technically feasible for cars, light utility vehicles, rail and local transport lorries without any further improvement. However, direct electric drive cannot in any way yet be suited to ships or commercially used aircraft. Globally, the technical potential of renewable energy is sufficient for producing electrically generated fuels using power from photovoltaic and wind turbine installations or solar thermal power plants where large amounts of energy are simultaneously used more efficiently. However, the power to gas and power to liquid technology is still in the research and development stage.

The transport sector currently accounts for about 18 percent of Germany's greenhouse gas emissions. These emissions, too, must decrease significantly in order to achieve the climate protection targets. The UBA study "Treibhausgasneutrales Deutschland im Jahr 2050" (Greenhouse gas neutral Germany in 2050)26 shows that very clearly. The scientific assessment of greenhouse gas emissions from electromobility and electrically generated fuels is highly complex. Depending on how the power industry develops globally, very different reduction effects may arise. If future energy supplies were entirely based on renewable energy, CO<sub>2</sub> emissions from electromobility and electrically generated fuels could drop to zero. However, CO<sub>2</sub> emissions for electrically generated fuels would be a multiple of conventional fuels in an energy system primarily based on fossil fuels (especially coal). Regardless of a national renewable energy supply in Germany, emissions may also occur that must be accounted for when upstream production processes - such as construction of energy installations, extraction of raw materials for batteries and steel for wind turbines - are considered. Figure 4 shows the

total greenhouse gas emissions as the sum of direct and indirect emissions of electrically generated fuels, conventional fuels and biofuels for 2050.<sup>37</sup> Assuming that the power for electromobility and electrically generated fuels comes from a German renewable energy supply, no greenhouse gas emissions will arise. The production of renewable energy installations is, however, wholly or partly abroad and is therefore burdened with "grey" emissions.<sup>38</sup>

Figure 4 shows that both the direct and indirect use of electricity ensures a significant benefit in climate protection compared to conventional fuels such as petrol and diesel from oil and 1st-generation biofuels currently being used. 2nd-generation biofuels also enable considerable greenhouse gas savings, but they are only suitable for niche applications because the amount of raw materials such as residues from timber production is limited. It is clear that without significantly more renewable energy in the German power grid, greenhouse gas emissions from electrically generated fuels would considerably exceed those of conventional fuels also because of conversion losses.

#### Figure 4:

## Greenhouse gas emissions per final energy including upstream chain emissions in gCO\_equivalent/MJ.

Biofuels are indicated without land-use changes. Ø renewable is based on the average 2050 renewable power. PtG stands for methane. Both PtG methane and PtL are based on atmospheric  $CO_2$ .

![](_page_38_Figure_16.jpeg)

Source: 39

#### MOBILITY OF THE FUTURE

#### ENDNOTEN

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of the environmental balance of electric ve-

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(EL: electricity, H: heat, CH: chemical energy

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both for conventional fuels and biofuels.

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eters, CO intensity of the stream or energy)

directly caused by an installation's operation

provision and extraction of raw materials for

the installation and other processes related to

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For this reason, discussing and establishing the necessary regulatory framework is crucial. In order to accelerate the advancement of the art and obtain a marketable technology, the UBA recommends the promotion of research and development in a targeted form and to further develop the legal and economic framework.

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I 1.1, I 1.3, I 1.4, I 2.1, I 2.2, I 2.3, I 2.5, I 3.1, I

#### Conclusion

The transport sector will only reduce its high greenhouse gas emissions when a fundamental change takes place. UBA believes that the trio of firstly, traffic avoidance, secondly, modal shift in transport and thirdly, technical improvement is of key importance. In addition to these building blocks of a transition in transport, a fourth block is to convert the traffic onto greenhouse gas neutral energy sources. Fossil fuels such as petrol, kerosene and diesel will still accompany us for a while, but will have become obsolete in the medium term. The future lies with renewable electricity for electromobility and electrically generated fuels. Therefore, in addition to transport transition, we need an energy transition in transport, otherwise we will miss these ambitious climate protection goals in the transport sector.

Transport policy and its implementation must fundamentally change course – and should be embedded in an overall concept. Isolated individual measures cannot be successful as the transport is closely linked with many other of society's policies such as economic, energy and environmental policies. Also, transport policy change takes place at different policy levels (UN, EU, federal, state and local authorities), which are often inadequately coordinated. Therefore, a holistic strategy is necessary in transport policy which is integrated into other policies and all policy tiers.

Examples from other European countries show that such comprehensive strategies in transport policy are possible. Austria created an "overall transport plan" strategy in which the different areas of responsibility for individual transport modes, different political tiers and adjacent areas of policy have been successfully integrated. It acts as a "red thread" for all stakeholders.

Germany should use these examples as a guidance and elaborate a mobility strategy for the action fields identified to place the transport sector on an environmentally sound and greenhouse gas neutral as well as economically and socially sustainable path by 2050.

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80

# The German Environment Agency

Protecting our drinking water and swimming-pool water

pp. 82–91

81

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## How safe is our drinking water and the water in public pools? Which research do we need to clarify this?

80 to 90 percent of Germans regularly enjoy safe drinking water from the tap. Rightly so, because drinking water regularly undergoes thorough checks. 99 percent of the drinking water samples comply with the strict legal requirements. But now that water analysis is getting more sensitive, impurities in very low concentrations can also be detected. This means media report about pharmaceuticals, painkillers, birth control pills or pesticides in the aquatic environment. Trace substances and pathogens get into some waterbodies through sewage or as run-off from agricultural land. Only a minute portion of such chemicals normally get into drinking water, and only in very low concentrations – in the range of a few millionths of a gram per litre. Yet how do we evaluate such new information? How do we assess what these findings mean for health: how high are the risks? under laboratory conditions. In nature and in large technical systems, it always contains various substances and micro-organisms at low concentrations - both those that are naturally present and those that are released into the water by human activities. Water uninfluenced by people contains minerals and metals from rocks occurring on the site, organic substances created by the microbial degradation of plant materials or other organic materials and also microorganisms. Some of these substances (such as arsenic, fluoride, uranium and chromium compounds) are harmful above a certain concentration. Also, some naturally occurring, harmless organic substances can react with disinfectants and create undesirable disinfection by-products or provide nutrients to bacteria. Some bacteria from the environment (unlike most pathogens) are not contagious, however they can cause serious infections if inhaled, swallowed or contact the skin of sensitive people at a sufficiently high concentration. Examples are Pseudomonas aeruginosa or Legionella. The fundamental principle therefore is: micro-organisms must have no chance of multiplying in our water distribution systems, pools and baths.

## Pathogens and pollutants: How little is little enough?

E"Zero risk" – both from harmful substances and microorganisms – exists neither in technical nor in natural systems. The question is: what is the level of risk we can tolerate in drinking water and in pools? For many substances we can specify a threshold of effect, i.e. they are toxic above a certain concentration. This is the case e.g. with nitrate or selenium. Our body even requires some substances in low concentration that are actually harmful at high concentrations (e.g. fluoride or copper). Therefore, for such substances we determine the threshold of their harmful effects in animal studies and set limits well below that threshold.

However, there are also risks (such as for cancer) for which no effect threshold can be determined. In theory a molecule of such a substance is enough to cause damage or impairment. The likelihood that it damages the "matching" site in the genome (DNA) again depends on the dose, i.e. the amount absorbed. Thus, for carcinogenic substances the dose also determines the poisonous effect. With regard to cancer, the maximum tolerated risk established in recent decades is such that a given substance in drinking water must not cause more than one case in a million people if each of them drinks two litres per day every day of their lifetime. This means calculates one additional cancer per year for all of Germany for approximately 80 million Germans who on average reach an age of 80 years. Since about half a million people a year fall ill in Germany due to cancer, the probability that one of these diseases was caused by a substance in drinking water is unbelievably small. By comparison, about 20,000 people get skin cancer each year in Germany due to too much exposure to natural UV radiation. Conversely, this means that the limiting values for carcinogenic

Drinking water is essential to life

In addition to drug residues from human and animal excreta or pesticides used in agriculture, undesirable substances can leach into drinking-water from pipes, seals, lubricants, valves and other parts of drinking water installations. Especially if they are made of unsuitable materials or have been incorrectly installed. Also, new highly sensitive measuring methods can detect pathogens, including viruses and parasites, even if they are present in the water only in very low concentrations. Concern about pollutants and pathogens is connected: if drinking water is obtained from surface waters, it is usually disinfected because pathogens can be present. Swimming pool water must contain disinfectant because infected people release some pathogens into the water - often without even being aware of carrying an infection. However, disinfectants not only react with pathogens but also with organic compounds in the water and produce so-called disinfection by-products that

may be harmful. The question is: what is more dangerous, the pathogens or these disinfection by-products?

## How can we best make use of our new results of research and evaluation?

Assessing health risks from contaminants – i. e. chemicals or pathogens – in drinking water is of great public interest. Our trust in reliably healthy drinking water is of crucial importance. We want to drink it fresh and cool, cook our food with it, shower and bathe in it and use it for many other household purposes. The health benefits of swimming are undisputed and worrying about infections, allergies or even cancer triggered by reactions with disinfectants should not tarnish our swimming pleasure.

One thing is clear: water can only be completely free of microorganisms and foreign substances

![](_page_41_Picture_15.jpeg)

substances in drinking water are very strict in Germany. This is the intention and aim: drinking water should not make one ill because it is essential to life.

For pathogens the risk also increases with the amount. Many types of bacteria such as typhoid and cholera only cause infection after uptake of a large number (e.g. about 1,000 bacteria). However, for others – in particular some viruses and parasites such as Cryptosporidium and Giardia - even 1 to 10 pathogens can cause a diarrheal disease. Thus, as with the chemicals, there can be no absolute certainty that no single pathogen ever reaches the consumer's tap. Therefore a maximum tolerable rate of illness should be established for bacteria, viruses and parasites as well. This finding is quite new and so far has only entered the legislation in the Netherlands: there, drinking water may cause an infection for a maximum of one in 10,000 people per year. The World Health Organization goes one step further and proposes to distinguish between mild infections (such as three days of diarrhoea) and severe infections (e.g. cholera and typhoid) by multiplying the disease rate by a weighting factor for the severity of the disease (such a procedure is familiar to many of us from disability insurance). In consequence, for such highly infectious pathogens the maximum tolerated dose would be e.g. one virus in 100,000 litres of drinking water- an extremely low concentration which cannot even be measured directly, only estimated.

Setting a maximum level of infection risk tolerated through drinking water is not a purely scientific task, but a social and political one as well. The German Environment Agency is currently looking for suitable forums for such discussions with the aim of developing a proposal for legislation from the discussion results. Such a health-based target is the basis for deriving maximum tolerable concentrations down to which pathogens need to be reduced – be it by natural processes or by treatment technology in the waterworks.

## Ensuring high water quality – despite a variety of substances and pathogens

In face of the many chemicals and pathogens that – in theory – could get into drinking-water, it would be a hopeless task to aim at safety through increasing the number of contaminants for which we set legal limits and require regular monitoring. The far more effective approach is to prevent pollutants and pathogens from getting into the water in the first place, and if they do get into water, to ensure that they are effectively removed. For this aim, it is sufficient to regularly check a selection of characteristic substances and micro-organisms in order to verify that water extraction, treatment and distribution always operate to reduce contaminants – always work the way they should.

The German Environment Agency therefore recommends to focus investigations on the "raw water" used to produce drinking water – i.e. the water from which drinking water is extracted -to estimate the maximum pathogen concentration to be expected, and to assess the drinking water extraction and treatment procedures in place to see if they are suitable to sufficiently and reliably reduce pathogen loads even at peak levels, or whether further treatment measures are needed (see UBA's recommendation on quantitative risk assessment of microbiological findings in raw water and consequences for the protection of the catchment area and for water treatment, 2014). Natural processes that remove contaminants from water include: biodegradation, "die-off" of pathogens, sedimentation of particles in a reservoir, the soil's filtration effect in bank filtration; technical processes in drinking-water treatment include flocculation, filtration and, if necessary, ozonation, activated carbon treatment or disinfection. For ozonation and disinfection it is important to take into account whether these oxidation reactions with organic matter will produce transformation products, which in turn may be harmful. Finally, the residual (measured or estimated) low concentrations in the fully processed drinking water must undergo a health assessment to see whether the risk specified as 'just tolerable' is not exceeded. To support such risk assessments, UBA in collaboration with the Technologiezentrum Wasser "TZW" (Water Technology Centre) has developed the compendium "Das Water-Safety-Plan-Konzept: Ein Handbuch für kleine Wasserversorgungen" (The Water Safety Plan Concept: A handbook for small water supplies) with practical explanations, suggestions, examples and supportive working aids.

Concept of a

http://www.um

fuer-kleine

TZW

Water Safety Plan:

A handbook for small water supplies

weltbundesamt.de/

publikationen/das-water-safety-plan-konzept-

![](_page_42_Picture_9.jpeg)

Each water supply is a specific and individual case; nevertheless, experience can be used to estimate the elimination performance of other systems under similar conditions. It is therefore important to combine and process this knowledge so that it is readily accessible for use in practice - as a "book of reference" or an ITbased guide. However, some important elements are still missing for such a reference: research is needed into the behaviour, transport, elimination or release and development of substances and pathogens in water bodies and sediments and likewise for the technical processes in drinking water treatment. Such research is carried out in the German Environment Agency's laboratories and pilot plants (which are large, full-scale test facilities) - often in cooperation with external partners such as universities, reservoir management or health authorities. Based on the research results, UBA represents the government's interests in drafting standards (DIN, CEN, ISO) and technical regulations (DVGW, DW). At our site in Bad Elster in the saxonian Vogtland we investigate and evaluate the occurrence of pathogens and contaminants in drinking water and swimming pool water:

- Die **Mikrobiologie** bewertet Methoden zum Nachweis von Krankheitserregern. Zum Beispiel prüfen wir derzeit, inwieweit schnelle genetische Nachweismethoden für Legionellen die langwierigeren Tests durch Kultivierung ersetzen können. Ein weiteres Ziel ist die Beurteilung des Gesundheitsrisikos durch Krankheitserreger im Trinkoder Badebeckenwasser. Werden Erreger im Wasser gefunden, unterstützt das UBA die Gesundheitsbehörden vor Ort bei der Suche nach Ursachen (siehe Kasten 1).
- Our **microbiology** unit evaluates methods for pathogen detection. For example, we are currently testing rapid genetic detection methods for Legionella to replace the lengthy tests using cultures. Another objective is to assess the health risk due to pathogens in drinking water or swimming pool water. Where pathogens have been found in water, UBA supports local health authorities in their search for the causes (see Box 1).
- Our **chemical analysis** unit improves analytical methods for specific chemical contaminants in order to investigate them in drinking water and swimming pool water, even at very low concentrations. For example, UBA currently heads a government-states working group for harmonising analytical methods for chromium (VI) because chromium (VI) compounds have been found to damage DNA. UBA carries out measurements to clarify the

![](_page_42_Picture_14.jpeg)

![](_page_42_Picture_15.jpeg)

![](_page_43_Picture_2.jpeg)

Biological two-stage processing plant in the UBA-operated waterworks frequency and concentrations at which certain substances occur in drinking water or swimming pools. We are currently investigating some 2,500 drinking water samples from the German Environmental Survey coveringa wide range of substances in order to check whether previously unrecognised pollutants occur in drinking water and if so, to what extent. The aim of our research is to clarify which substances can emerge from chemical reactions in water, for example, when urea introduced by swimming pool visitors (via the skin or urine) reacts with disinfectants such as chlorine, to form trichloroamine which can irritate the respiratory system and promote allergies (see Box 2).

• Our toxicology unit develops rapid tests to evaluate the health relevance of substances that can be found in low concentrations in water samples such as pharmaceuticals or personal care substances. For this purpose, animal studies have been replaced with a series of tests using cell systems that show whether a substance exerts any effect. These in particular are tests on genetic, neuro or cell toxicity; and tests for hormonal effects have recently been added. UBA promotes the development of such test systems for a range of purposes, including the aim that they should be standardised and eventually become part of legislation. The UBA Toxicology Section heads the integrated research programme "ToxBox" (see http://www.umweltbundesamt.de/themen/wasser/trinkwasser/ trinkwasserqualitaet/toxikologie-des-trinkwassers/projekt-tox-box) within the major funding initiative "Risk management of new pollutants and pathogens in the water cycle ("RisKW") of the Federal Ministry of Education and Research (BMBF). In particular, the toxicology unit clarifies whether substances that are conspicuous in chemical analysis

such as the above-mentioned trichloroamine in the swimming pool air, are actually harmful (see Box 2).

In addition to this method- and evaluation-oriented research, UBA also conducts research on the drinking water supply chain, i. e. the processes beginning with the resource, through water extraction and treatment to distribution to the consumer's tap.

- Water resources are the water bodies including groundwater - from which drinking water is extracted. One focus of the UBA research carried out in the Berlin-Marienfelde pilot plant is to study the efficiency with which sediments can retain contaminants (e.g. cyanobacterial toxins or nanoparticles) and pathogens (especially viruses) through bank filtration in drinking water extraction. These large pilot-scale facilities provide the opportunity to carry out such tests under conditions which are very similar to those in the real world. They provide the reality check whether results gained in the laboratory can be transferred to the real-world conditions. The results of this research have been incorporated in structured assessment tools (see www.viren-im-wasser.de and http://toxische-cyanobakterien.de). They lead through online questionnaires for the assessment of the extent in which the presence of viruses or cyanobacterial toxins can be expected and also link to relevant background information.
- In Berlin-Marienfelde, UBA studies methods of **drinking water treatment** for small suppplies such as those for the elimination of pathogens in disaster situations and for the biological removal of naturally occurring metals such as iron, manganese and chromium(VI). Furthermore, it develops efficacy criteria for disinfection methods using a test rig specifically developed at UBA for this purpose.
- In Bad Elster, Saxony, UBA's staff deal with drinking water distribution to clarify how materials in contact with drinking water, for example in pipes, fittings and faucets, release substances into the drinking water (see Box 3) and to develop test methods. Based on the results, UBA also establishes test result evaluation criteria. The German Drinking water Ordinance, as amended in 2012 will make compulsory these hitherto voluntary requirements in a few years. Furthermore, this unit checks whether or not product testing and evaluation by third-party certifiers functions properly in practice: they do this by testing certified plumbing products purchased on the market in their own laboratory, applying the current procedure for certification.

#### BOX 1: Tracing diarrhoea: microbiologist detectives

In the summer of 2013 in Halle/Saale, more than 160 people fell ill due to the parasitic diarrhoea pathogen Cryptosporidium, most of them in the week from 19 to 25 August. The source of infection was unclear and it was not known whether there was a connection with the great flood that reached its peak at the beginning of June 2013 and flooded large areas of Halle.

In August, the German Environment Agency (Section II 3.5), in close cooperation with the City of Halle Health Authority and the Robert Koch Institute in Berlin (Department for Infectious Disease Epidemiology, Section 35), started site investigations. Initially, samples were taken from the water supply network, all of which proved in compliance. This allowed an immediate lifting of the compulsory boiling of drinking water previously imposed by the local Health Authority.

Furthermore, swimming pools, which were affected to a greater or lesser extent by the flood were tested, as well as water in the river basin of Elster and Saale in the City of Halle area. The results showed high Cryptosporidium concentrations in certain parts of the Saale and its tributaries even long after the flood.

Pathogens were also found in swimming pools, which were then temporarily closed. However, it is now assumed that the swimming pools were not the primary source of the infections, rather visitors that carried Cryptosporidium to the pools. Therefore, the question of the source of Cryptosporidium was still unclear.

Since they were found at high concentrations in the river system, the most likely pathway now assumed is that Cryptosporidia from wastewater and/or flooded pastures entered the river (and persisted there even long after the flood) because they can infect humans as well as livestock and wildlife. In addition, despite warnings from the authorities, many people took advantage of the flooded areas for recreational activities. A small amount of Cryptosporidium entering the digestive tract with contaminated water through the mouth is sufficient to cause an infection. Infected people can excrete pathogens over many days, without being aware of this – for example, when they visit a swimming pool. The most likely primary cause of the disease wave was therefore the public coming into contact with the presumably highly polluted flood waters.

The conclusion from the findings is that in the event of flooding, bathing in flooded areas can lead to an increased infection risk by pathogens of faecal origin, especially when the flood sweeps out contaminants from sewage systems or pastures.

Pathogens are frequently detected in rivers even at normal water levels, in particular downstream of wastewater discharges because wastewater treatment plants can only partially remove pathogens. In addition to the risk of accidents through boat traffic, this is the main reason why bathing areas are rarely designated in rivers.

![](_page_43_Picture_19.jpeg)

#### BOX 2: Chlorine smell in the swimming pool? Not necessary!

Whether swimming in chlorinated swimming pool water increases the risk of asthma for infants is the subject of a scientifically controversial and highly emotional debate. Belgian scientists developed the "chlorine hypothesis", which attributes a crucial role in the process of asthma development in children swimming in chlorinated pool water in early childhood: according to this hypothesis, trichloroamine (nitrogen trichloride, NCl3) penetrates into the lower respiratory tract through breathing the swimming pool air and damages the lung epithelium, so that allergens can more readily provoke asthma attacks.

Trichloroamine arises as an unwanted by-product from chlorination of pool water – among other chlorine-nitrogen compounds. Trichloroamine is an extremely strong irritant to eye conjunctiva, nose and throat mucous membranes and bronchial tubes, similar to the irritant effect of chlorine gas. Its chlorine-like, intense smell is the main cause of the typical indoor swimming pool odour. Trichloroamine arises when urea – introduced by the bathers via the skin, sweat or urine into the water – reacts with chlorine dissolved in the bathing water to produce trichloroamine. Trichloroamine then outgases from the water, this can accumulate in the indoor pool air and cause respiratory irritation. Therefore, breathing is the main absorption path for bathers and personnel in indoor pools. Thus, it is necessary to clarify the extent to which trichloroamine occurs in the indoor pool air, what concentrations can cause health risks and how these risks can be avoided.

UBA's laboratory was the first laboratory in Germany to establish an analytical method for the determination of trichloroamine in indoor pool air in 2006 and to carry out measurements in indoor swimming pools. It found that the concentration in the indoor pool air quickly and sharply increased, particularly when ventilation was poor. These results prompted UBA to publish a recommendation on the proper ventilation of indoor swimming pools.

UBA has investigated the potentially asthma-inducing effect of trichloroamine in various projects funded by the BMBF. By means of the exposure model "Vitrocell®" human lung cell linings were exposed to trichloroamine. Trichloroamine leads to an enhanced release of inflammatory parameters, especially in previously damaged lung cells, which play a crucial key role in the process of asthma development.

Based on these results and literature data from epidemiological studies, experts of the ad hoc working group 'Interior Guidelines' of the Indoor Air Hygiene Commission of the German Environment Agency and the Supreme State Health Authorities carried out a health assessment for trichloroamine in indoor pool air. The result is the German Environment Agency's publication: "Health assessment of trichloroamine in the indoor pool air". It proposes a maximum value for trichloroamine in indoor pool air of 0.2 mg/m<sup>3</sup>. This value is designed to chiefly protect pool users and personnel against irritation. UBA's measurements of air pollution in various indoor swimming pools confirmed that the standard is technically acheavable in swimming pool practice.

Furthermore, UBA has comprehensively informed the public about trichloroamine in swimming pools because the lower the concentration, the less the health risk. The press release "Baby swimming – asthma risk due to chlorine disinfection?" points out the health risk for children under the age of two. A Parents' Guide was also compiled in cooperation with the Research Group Environmental Medicine in the Society for Paediatric Allergology. This guide suggests that "(...) within the U4 to U7 (medical checks at ages 4 to 7 months) paediatricians should individually advise high-risk families or currently allergic children to restraint from baby swimming".

Since trichloroamine is primarily produced from urea from the visitors via the skin, sweat and urine in chlorinated water, the reduction strategy is simple: all swimming pool visitors, not only children, should strictly comply with the principles of personal hygiene: showering thoroughly before bathing and not using the swimming pool as a toilet.

#### **Parents' guide:**

http://www.gpau.de/fileadmin/user\_upload/GPA/dateien\_indiziert/Elternratgeber ER\_2014\_3-14.pdf

#### Flyer:

http://www.umweltbundesamt.de/themen/wasser/schwimmen-baden/schwimm-badebecken/wasserqualitaet-der-schwimm-badebecken

#### Film:

Gesund wie ein Fisch im Wasser: https://www.youtube.com/watch?v=V9y6m-khBVo

Trichloroamine in the air is a strong irritant. UBA recommends proper ventilation of indoor pools.

![](_page_44_Picture_17.jpeg)

![](_page_45_Picture_2.jpeg)

#### BOX 3: Pipes and fittings – hygienically safe

Drinking water plumbing in residential buildings has become rather complex in recent decades. It consists of a number of materials, i. e. metallic materials such as copper or stainless steel, various plastics and lubricants. Depending on the design of drinking water plumbing, water often stagnates over extended periods of time, especially if the water is centrally heated in the basement in large buildings and then has to pass through the whole building. Therefore products that are in contact with drinking water have to be assessed thoroughly. Pipes, fittings, hoses and other components must not release any substances into the drinking water in concentrations that can be harmful to health, adversely affect the smell or taste of drinking water or "feed" the growth of larger numbers of microorganisms. The aim of UBA's research initially was the development of test methods for different materials. These include guidelines on how the various materials are to be exposed to the test water and which properties the test water must have. Depending on the materials to be tested, these guidelines differ significantly, especially between those for metalsl and those for plastics. Metals in contact with drinking water form a sealing layer on the materials through corrosion; this can often reduce the further release of their constituents into the drinking water. For this process, the chemical composition of the drinking water (e.g. hardness and pH) has a crucial role. All these factors must be considered in the test. In contrast, for testing plastic materials layer formation and the properties of the water are not crucial.

In a second step, UBA laid down the criteria for evaluating the test results. To this end, it carried out investigations in order to compare the results of tests that are carried out under harsh conditions to results of tests under more realistic conditions. After consultation with numerous experts in specially organised committees UBA used the results

of this research to develop guidelines and recommendations for testing and evaluating the products – both for metals and for organic materials. At present, UBA is working particularly with partners from France, the Netherlands and the United Kingdom to harmonise criteria within the EU.

To test the effectiveness of the requirements, UBA has bought more than 30 different plastic tubes in recent years and tested them in its own laboratory for release of substances and the influence on odour and taste of drinking water. It found that not all products certified for drinking water adhered to the requirements of the UBA guidelines, although they were certified on this basis. Warm water samples from these pipes, in particular, exceeded the requirements for odour. If the water smells of "chemicals" after long periods in a plastic tube, this does not necessarily mean that the substance causing the odour is harmful. As a precautionary measure, and because drinking water should be pure and tasty, the UBA guidelines specify a low odour threshold value. These findings led to the detection of weaknesses in the certification process, which is currently being improved. This example showed the high value of UBA's ability to use UBA's own tests to independently pinpoint weaknesses in other bodies' assessments.

In addition, based on these data UBA once again confirms the golden rule: always use water fresh and cool from the tap – do not give it time to absorb substances from the pipe materials. This is a very simple way to ensure that water for drinking and food preparation does not contain contaminants that have been released into the drinking water from materials.

## Editorial information

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