The Impact of Transport on the Environment

By
Prof. Dr. Robert Sausen

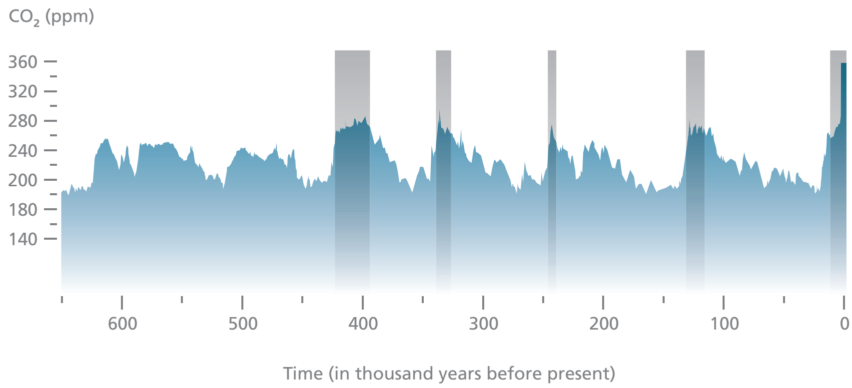
Since the middle of the 18th century, humans have been using increasing amounts of fossil fuels, beginning with coal and then later moving on to crude oil and natural gas. This enabled industrial production to develop to such a tremendous rate. The wealth of the people increased in many parts of the world. However, burning coal, oil, and gas has a number of adverse effects. The Earth's atmosphere is changing. Never before has man interfered so much with the planet's climate system. We are continuing to do so at increasing rate, in particular via our transport system. What are the consequences? This is what climate researchers at DLR in Oberpfaffenhofen are investigating.

The greenhouse gas carbon dioxide (CO_2) is generated when fossil fuels are burned. Due to their optical properties, greenhouse gases lead to an increased temperature at soil level and in the troposphere, which is the lowest atmospheric layer. The greenhouse effect also exists without human interference. It is primarily caused by water vapor, CO_2, ozone (O_3), methane (CH_4), and nitrous oxide (N_2O). Without this natural greenhouse effect, the temperature on earth would be some 30 degrees centigrade lower.

Man has considerably interfered with this natural system by emitting additional greenhouse gases. This can be proven by analyzing air which was trapped in the Antarctic ice several hundred thousand years ago and was "archived" this way. According to the findings in this air, during the last 650,000 years the CO_2 concentration in the atmosphere was always below 300 parts per million (ppm), which means below 300 CO_2 molecules per 1 million air molecules. This CO_2 concentration rose quickly from approximately 280 ppm in the

Timeline of the development of atmospheric CO_2 concentration during the last 650,000 years; data from ice core. The last 50 years tally with measurements in the Antarctic air. The vertical gray bars mark the warm interglacial periods.

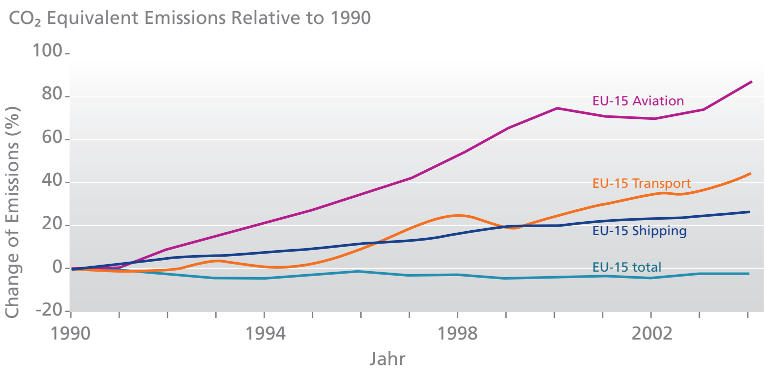
According to IPCC (2007)



middle of the 18th century to 379 ppm in the year 2005. Other greenhouse gases are revealing similar developments. The methane concentration, for example, had a pre-industrial level of 715 parts per billion (ppb), i.e., 715 CH_4 molecules per 1 billion air molecules, and has risen to more than twice its original value: 1774 ppb in the year 2005. Apart from the naturally existing greenhouse gases, man has also emitted some which only exist due to human activity. These include, e.g., chlorofluorocarbons (CFC) and sulfur hexafluoride (SF_6), also called heavy gas.

These (anthropogenic) greenhouse gases that have been additionally emitted by mankind into the atmosphere are leading to a further temperature increase in the troposphere. This warming effect is further amplified by feedbacks in the climate system. The atmosphere absorbs more water vapor when temperatures are higher. This water vapor in turn also functions as an additional greenhouse gas, causing the troposphere to heat up even more. The ground level air temperature has increased by a global average of 0.75 degrees centigrade over the past 100 years.

Eleven of the twelve years between 1995 and 2006 are among the hottest years since the beginning of regular instrumental ground level temperature measurements in 1850. Paleoclimatic analyses have revealed that at least within the last 1,300 years it has never been as hot in the Northern hemisphere as it has been in the past 50 years. The Arctic has never seen temperatures as high as today within the past 130,000 years. There is a high probability that a large proportion of the temperature increases of the last 100 years have been caused by man.



Changes in CO_2 equivalent emissions of the EU-15 relative to the emissions in 1990. All anthropogenic emissions are depicted in turquoise, transport emissions in orange, emissions from international aviation in magenta and from international shipping in blue.

Source: UNFCCC

The Intergovernmental Panel on Climate Change (IPCC) has analyzed several potential developments in society and the resulting greenhouse gas emissions during the next 100 years. Depending on the choice of scenario, the forecast for the temperature increase by the end of this century, i.e., the year 2100, lies between 1.1 and 6.4 degrees centigrade. The lowest values can only be achieved, however, if drastic cuts in greenhouse gas emissions are made. The increase in global temperature is simultaneously reflected in changes in the weather: The melting of the arctic sea ice, more frequent and intense rainfall, more frequent severe storms – the consequences cannot be overlooked.

Transport contributes significantly to the greenhouse gas emissions: Road traffic, aviation, and shipping contributed 13.8 percent, 2.2 percent, and 2.7 percent respectively to the anthropogenic CO_2 emissions in the year 2000. In order to reduce greenhouse gas emissions, the United Nations passed the Kyoto Protocol in 1997. By 2012, the EU and its member states (before the enlargement to include the Eastern and South-Eastern European states) are accordingly required to reduce their CO_2 emissions equivalents by 8 percent relative to the value in 1990.

When calculating equivalent CO_2 emissions, the other Kyoto Protocol gases (methane, nitrogen dioxide, sulfur hexafluoride, chlorofluorocarbons, perfluorocarbons) are converted into the amount of CO_2 which has the same radiative effect over a time horizon of 100 years.

By the year 2004, the respective 15 EU member states achieved a reduction in their anthropogenic CO_2 emission equivalents of 2.6 per cent.

However, transport emissions (including those from national aviation and national shipping) increased by 26 percent in the same time period. The emissions from international aviation and shipping ("bunker fuels") originating in the EU have even increased by 87 percent and 43 percent respectively. The relatively strong increase of transport emissions occurred because the growth in transport volume was so fast that it has outstripped the effect of substantial reductions in specific emissions from technological progress.

However, making transportation a scapegoat in the current climate debate would mean ignoring the fact that it signifies an essential component within our globally linked economic

Complex Task – Far-reaching Cooperations

In order to analyze the effect of transportation on noise emissions, air quality, and climate change, DLR is cooperating with partners in Germany, Europe, America, and Asia. DLR cooperatse with the Research Center Karlsruhe (Forschungszentrum Karlsruhe – FZK) in the area of harmonizing forecasts of noise and local air quality, taking into account meteorological influences. Joint indicators will help to avoid competing measures for noise reduction or improving air quality.

A similar situation is found in the area of studying the effects of transport on the composition of the global atmosphere and climate. Here, DLR is coordinating the EU Integrated Project QUANTIFY (Quantifying the Climate Impact of Global and European Transport Systems). More than 100 scientists from 41 institutions from 19 countries (Europe, Asia, and America) are involved. This way, not only experts from a diverse range of disciplines come together but also uncertainties resulting from incomplete scientific knowledge can be better evaluated through the combination of independent tools (measurement devices, models, etc.). The EU project ATTICA was derived from the QUANTIFY project. ATTICA's core aim is to create a European assessment report of the effects that transportat has on the atmosphere and climate.

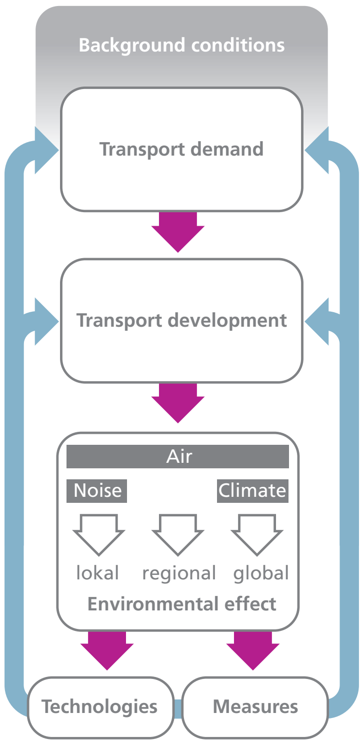
systems. The social need for mobility and the transport of goods is directly linked to the efficiency of the transport system. Both aspects need to be taken into account.

DLR is researching into transport as a whole in order to identify the scope for action between the desired properties of transport and its negative consequences. High transport demand leads to an increase in traffic, and the resulting emissions cause noise, reduced air quality, e.g., through particulate matter or smog, and cause climate change. In order to tackle these environmental effects, new technologies such as particulate filters or jet engines with lower nitrous oxide emissions are being developed and regulatory measures are being taken (e.g., setting emission standards or speed restrictions) which are aimed at lowering overall emissions in absolute terms. Both technologies and measures influence transport demand and traffic development. This creates a closed feedback circuit.

The DLR Institute of Atmospheric Physics is concentrating on the environmental impact of transport. One focus is placed on the impact of transport on the composition of the atmosphere and on climate. Even if the institute was only interested in analyzing the effects transport has on the climate, considering its consequences for the chemical composition and the abundance of particulate matter in the atmosphere is imperative.

Transport not only emits persistent greenhouse gases, such as CO_2 or nitrous oxide, it also changes the climate in other ways. These effects include greenhouse gases which do not become homogeneously distributed in the atmosphere, such as water vapour. Water vapour is particularly important in the case of very high-flying aircraft. Another example are emissions of ozone precursors such as nitrogen oxides, which impact

Process Chain "Traffic and Environment"



the atmospheric ozone abundance through chemical reactions, in particular resulting in an increased ozone concentration at ground level. Furthermore, the emissions of particulate matter or their precursors need to be considered because they influence the radiative balance in the atmosphere through dispersion and reflection. Another aspect to analyze is the formation of additional clouds such as condensation trails (contrails) or so-called contrail cirrus as well as the change in natural cloudiness caused by additional particulate matter in the atmosphere.

The diverse research in this area will provide answers to questions such as the following: How great are the climate effects of individual modes of transport such as road traffic, rail, shipping, or aviation? How can, in on scientifically sound bases, non-CO_2 emissions be integrated into existing emissions trading systems such as is being developed by the EU for the gases listed in the Kyoto Protocol? How great is the benefit of using biofuels or does their use lead to an even stronger climate change?

DLR researchers will be answering these and further questions concerning the effects of transport on the environment over the next few years. The DLR Institute of Atmospheric Physics is thus performing measurements (engine exhaust directly at test rigs, airborne in exhaust plumes of aircraft and ships, from space via satellites) and is simulating the developments in the atmosphere using comprehensive climate-chemistry models.

An example is a cooperation with MAN to analyze gases and particulate matter in the exhaust from ship diesel engines. The DLR research aircraft Falcon measures the exhaust in plumes of large ships. By this means DLR gains information about non-linear conversion and deposition processes that occur when the ship exhaust gases is diluted in the surrounding background air. A good understanding of these processes is required for appropriately taking into account major individual sources of polutants such as ships or aircraft in climate-chemistry models.

Satellite data will be used to study the transformation of contrails into contrail cirrus and to quantify the assoicated cloud clover. Similarly, the cloud cover of ship tracks, (line-shaped low clouds triggered by by particulate emissions from ships) is being determined from satellite data. The information about the cloud coverage will support an estimation of the climate effect of these clouds.

By performing numerical climate-chemistry simulations the DLR Institute of Atmospheric Physics will calculate the dispersion, conversion, and dry and wet deposition of traffic emissions. Results will be information about the long-range transport of the emissions and their follow-up prodcuts, and their impact on the composition of the atmosphere.

Eventually, the contribution of individual modes of transport to climate change will be able quantified and patterns of transport-related climate change can be revealed. The knowledge of these complex interactions will finally enable the definition of suitable measures for evaluating and regulating transport emissions.
http://ip-quantify.eu

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Prof. Dr. Robert Sausen has been managing the department "Atmospheric Dynamics" at the DLR Institute of Atmospheric Physics since 1991. The department is primarily concerned with the climate-chemistry modeling and the propagation of sound in real atmospheric conditions. An important field of application are the environmental effects of transport. Prof. Dr. Sausen coordinates the EU projects QUANTIFY and ATTICA.