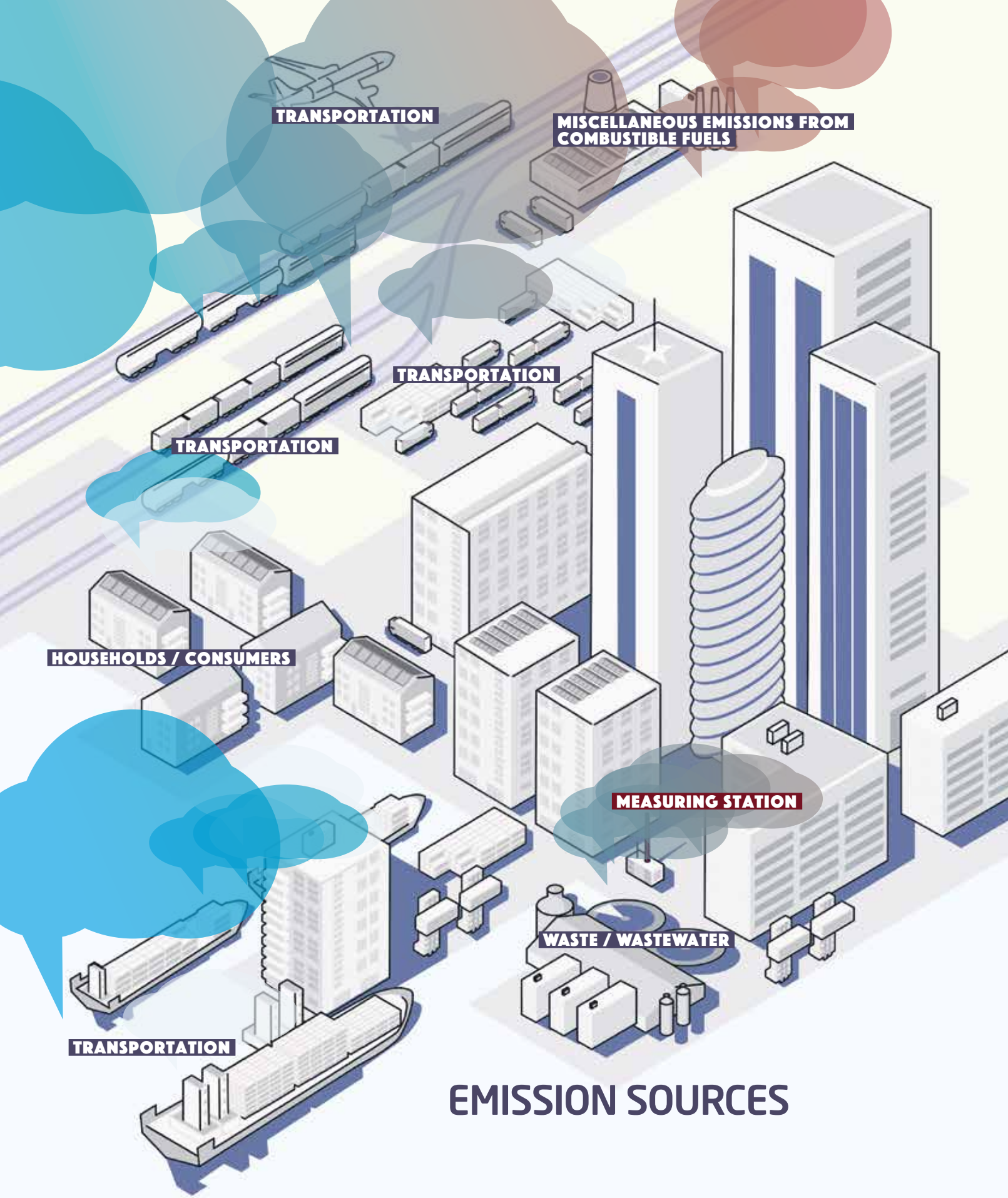
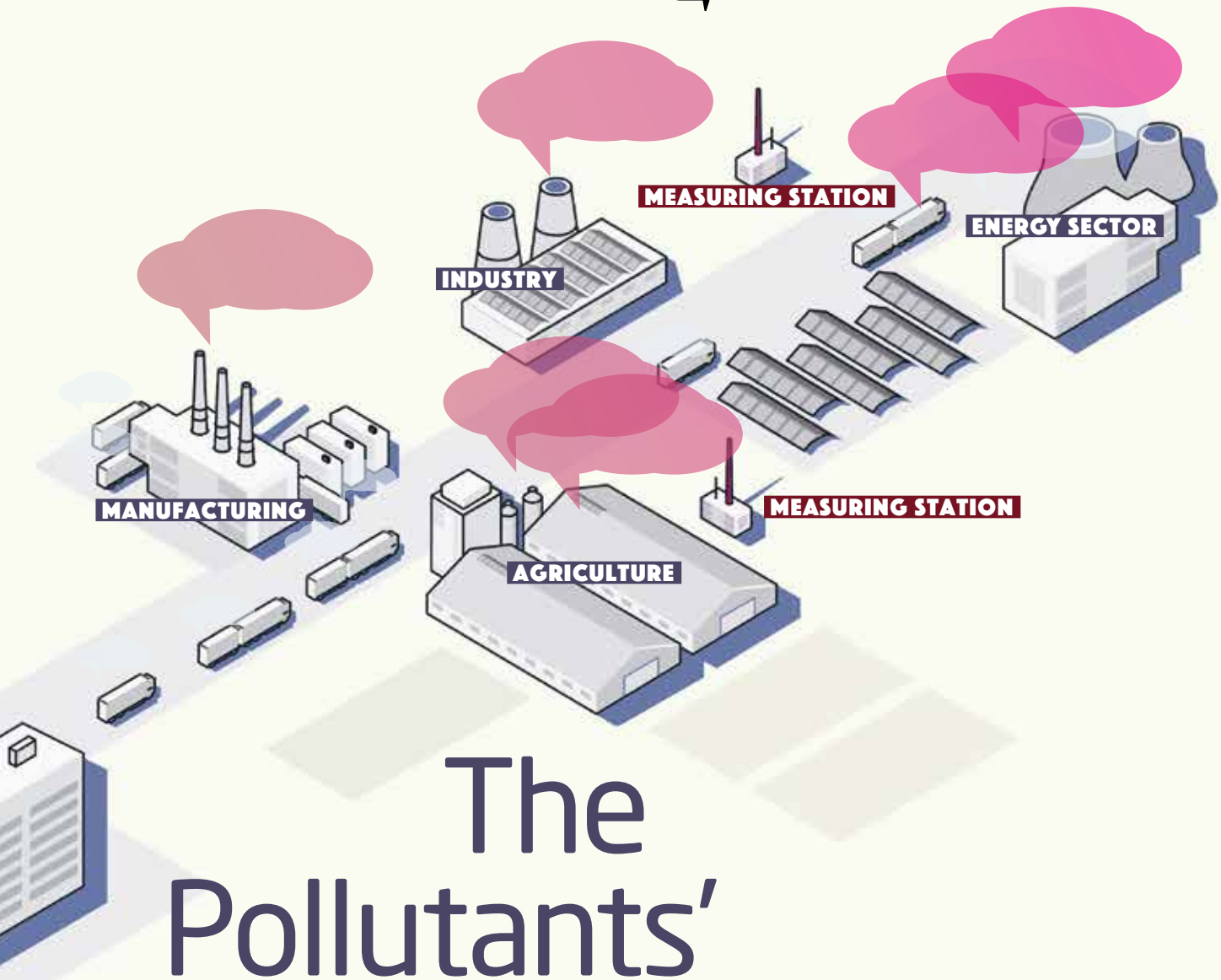


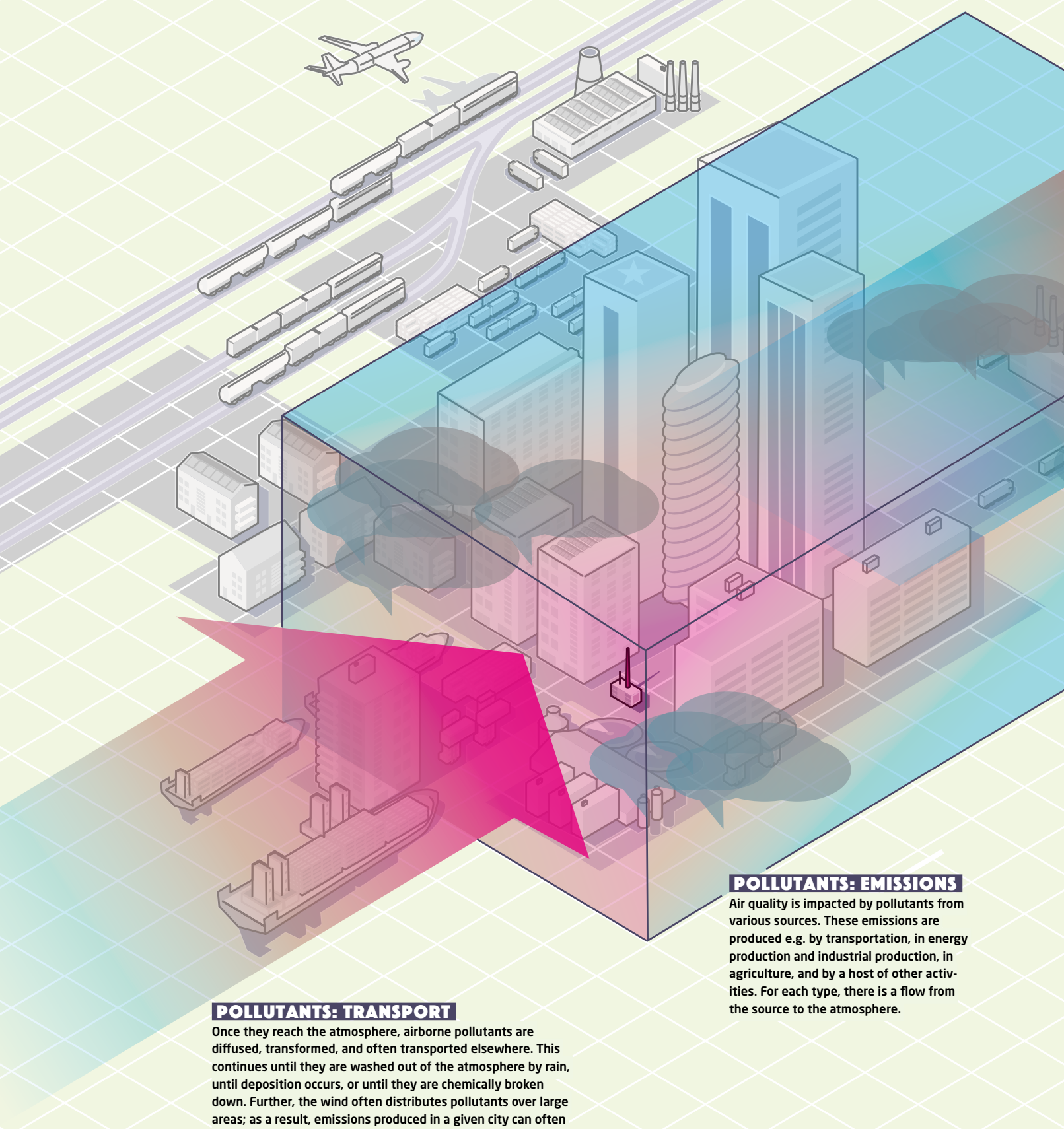
EMISSION SOURCES



The Pollutants' Journey

TEXT: TIM SCHRÖDER

Nitrogen oxides and other pollutants that are released into the air by automobiles or power plants can lead to illness and have a significant influence on our climate. This is why there are now various efforts across the country to more accurately measure their total concentrations. However, that is no mean feat. By means of a complex computer model, the experts from the Forschungszentrum Jülich are helping government authorities measure current pollution burden.



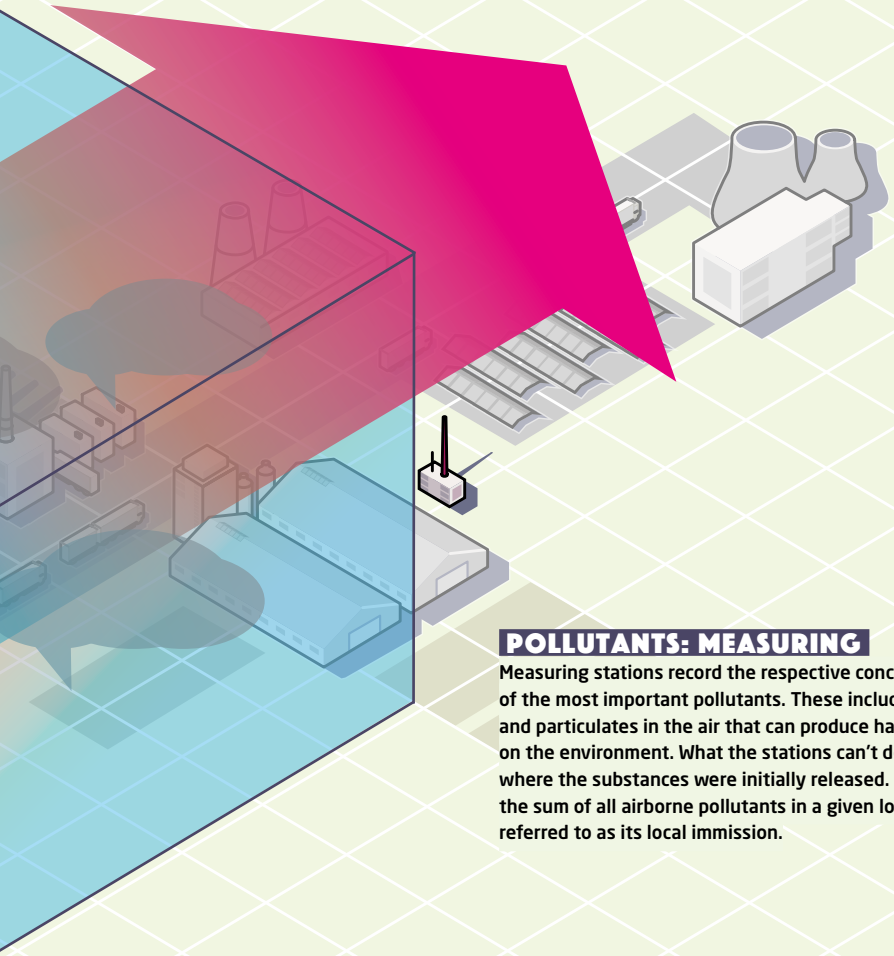
POLLUTANTS: EMISSIONS

Air quality is impacted by pollutants from various sources. These emissions are produced e.g. by transportation, in energy production and industrial production, in agriculture, and by a host of other activities. For each type, there is a flow from the source to the atmosphere.

POLLUTANTS: TRANSPORT

Once they reach the atmosphere, airborne pollutants are diffused, transformed, and often transported elsewhere. This continues until they are washed out of the atmosphere by rain, until deposition occurs, or until they are chemically broken down. Further, the wind often distributes pollutants over large areas; as a result, emissions produced in a given city can often affect the air quality in neighbouring communities.

POLLUTANTS



POLLUTANTS: MEASURING

Measuring stations record the respective concentrations of the most important pollutants. These include gases and particulates in the air that can produce harmful effects on the environment. What the stations can't determine: where the substances were initially released. Accordingly, the sum of all airborne pollutants in a given location is referred to as its local immission.

When it comes to air pollution, right now most people in Germany seem to have just one topic in mind - the diesel scandal and the nitrogen oxides that are emitted e.g. by diesel vehicles. Though there are currently debates as to whether the measuring stations have been deployed to the right locations, and whether or not they produce reliable data, the real question is what we can do to provide cleaner air in our cities. After all, not only can air pollutants and particulates lead to health problems; they also influence our climate – especially by aerosols, which, depending on their optical characteristics, can effect the temperature.

Of course we would have less air pollution if there were fewer cars on the roads. But does that mean we should make some streets off-limits for diesels, and if so, which ones? And do such measures really make a difference? This question may seem to be trivial. But there aren't any easy answers, because nitrogen oxides and many other air pollutants don't always produce effects where they are originally released; the wind can carry them for kilometres. And in the course of their journey, they can undergo chemical changes and form new compounds, which can be problematic by their own.

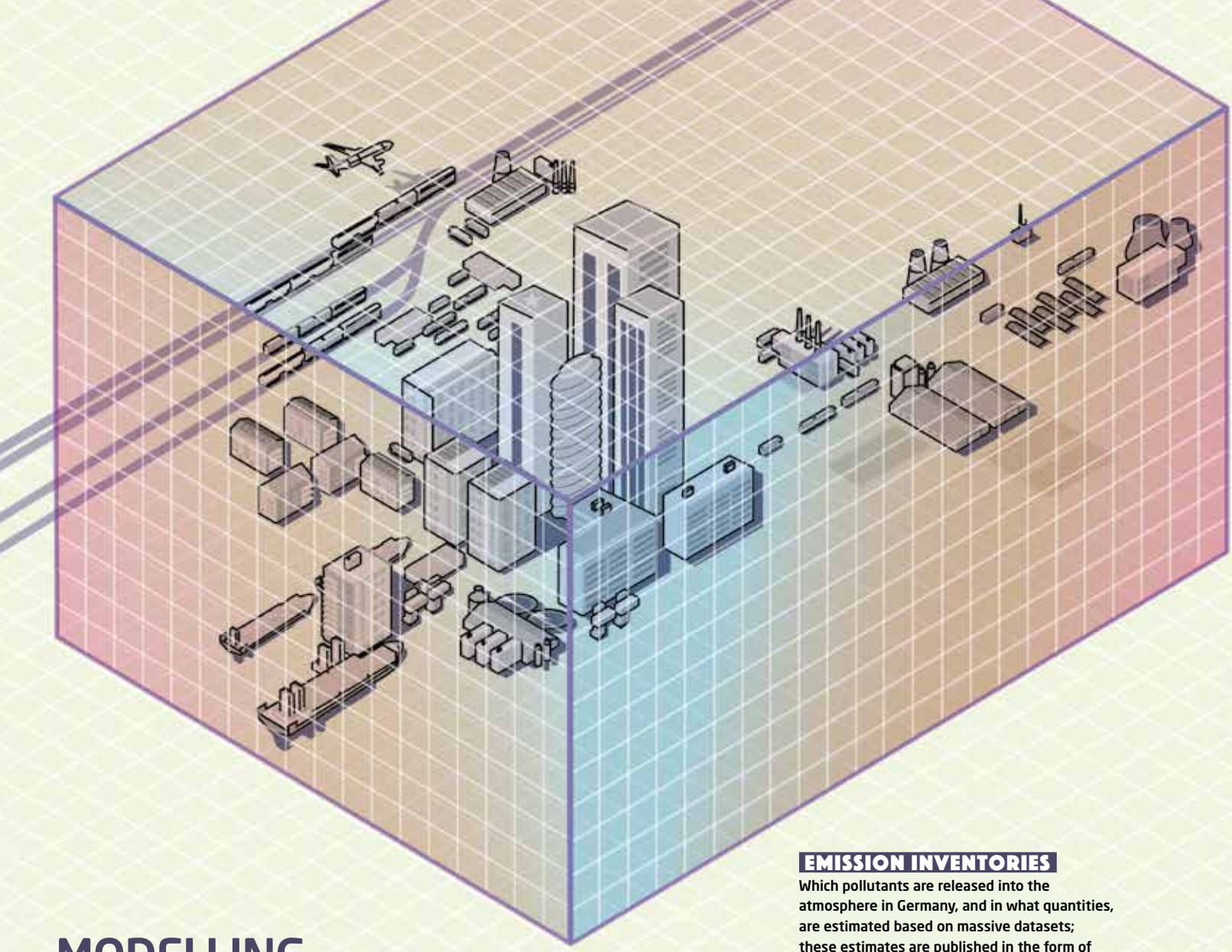
For example, in the densely inhabited Ruhr region, one city's emissions can cause the nitrogen oxide levels to climb in a downwind city. And when harsh winds blow from the east in bitterly cold winters, in some parts of Germany the values for nitrogen oxides or particulate concentrations can rise, because many domestic homes in Eastern Europe are still heated with coal. Accordingly, when we record the pollutant levels at a given location, we need to first determine where those pollutants come from, before we can introduce targeted measures to preserve the air quality.

Painstaking data gathering

One problem is that only very few emitted pollutants are measured directly. Measuring stations are predominantly located in major cities and metropolitan regions – and even there, mostly at a handful of sites. Consequently, no one knows exactly how dirty the air in Germany is, or to what extent pollutants affect the local climate. Hence, government authorities have to rely on estimates. They painstakingly gather data on all potential sources of pollutants: the number of registered vehicles and the sizes of their engines; the number of vehicles that use certain highway segments; the numbers of homes that use gas, oil, and electric heating; the pollutants generated by individual industrial plants; and the number of power plants and their operating hours. All this data is combined to calculate the annual pollutants and emissions for specific cities, counties, states, and Germany as a whole. These estimates are then published by the State Ministries of the Environment by tables and maps, which are referred to as 'Emission Inventories'. These inventories are in turn used to estimate the level of air pollution for specific regions, and what can be done to improve it.

Not always on target

Even though these professionally prepared estimates draw on a wealth of data, they don't always match with reality, and measurement stations often report different pollution levels than those suggested by the inventory. "That means that certain data or underlying assumptions used in the estimates don't reflect reality," says Dr Hendrik Elbern from the Forschungszentrum Jülich (FZJ). The meteorologist is a numerical modelling specialist and has made



EMISSION INVENTORIES

Which pollutants are released into the atmosphere in Germany, and in what quantities, are estimated based on massive datasets; these estimates are published in the form of 'emission inventories'.

MODELLING

it his goal to find the inconsistencies in the system and their causes, so that government authorities can more accurately estimate the actual air pollution levels in the future.

To do so, Elbern has worked together with doctoral candidate Annika Vogel and his colleagues Dr Anne Caroline Lange and Dr Philipp Franke from the Rhenish Institute for Environmental Research at the University of Cologne and the FZJ's Institute of Energy and Climate Research to develop a complex computer model specially designed to approach the problem from a different angle. It uses the values measured at the stations, compares them with the data from the inventory, and seeks to identify potential sources of error and deviations. It varies certain model parameters, especially those that the inventory data is based on, so that the inventory ultimately offers a good representation of the actual measured values. This approach has been previously used in the geosciences, but until recently, this type of modelling was assumed to be computationally unfeasible for atmospheric chemistry. The reason: more than 100 different chemical compounds and types of particulates have to be kept in mind. Nevertheless, Hendrik Elbern began developing his modelling tool, EURAD-IM: a powerful tool that contains a wealth of information.

Bearing in mind complex chemical interactions

A central element of EURAD-IM is the chemical transport model, a software component

ERROR DETECTION WITH MODEL

A computer model compares the values recorded at measuring stations with data from the emission inventory and identifies systemic deviations. By painstakingly assessing the inventory's underlying data, it helps to detect and correct sources of error, ensuring that the revised inventory ultimately provides a faithful representation of the actual measured values.

LOOKING AHEAD

Our goal is to represent the cycle of all airborne pollutants in our model, and the process to identify the sources of emissions, so that suitable countermeasures can be implemented: in terms of both short-term traffic control and power-plant management, and of long-term city and spatial planning.

HENDRIK ELBERN
Meteorologist, Forschungszentrum Jülich (FZJ)

that includes information on all the chemical reactions that can affect pollutants in the atmosphere. "There are hundreds of different reactions that can cause airborne pollutants to form or change," says Elbern. Just how complex this interplay is can be seen in the example of the chemical reactions between nitrogen oxides and ozone. Ozone especially forms on cloudless summer days, when nitrogen oxides bond with a plethora of different hydrocarbons, some of which are also emitted by plants. Accordingly, ozone isn't directly released as an emission, but is instead produced by a chain of chemical reactions set off by UV light. In turn, especially ozone and nitrogen monoxide react with one another in the atmosphere, rising the concentration of nitrogen dioxide (NO_2), which has received a great deal of attention thanks to the diesel scandal. In other words, the actually recorded NO_2 concentration can be influenced by any number of factors. "Our chemical transport model takes all known of these relations into account," explains Elbern. And the computer model is of course also supplied with extensive meteorological data – on the wind direction, humidity, or precipitation, which can wash away pollutants.

Experts refer to the method that Hendrik Elbern and his team use in order to clarify discrepancies between emission inventories and actually measured values as inverse modelling. It is 'inverse' in that Elbern uses the measured value to identify errors in the data used to create the inventory. According to Elbern, "Ultimately, our research consists in improving the data to such an extent that the inventories represent actual emissions as accurately as possible."

Supporting the Federal Environment Agency

Elbern has been working together with the Ministry of the Environment in North Rhine-Westphalia for the past several years in order to optimise the state's emission inventory. In a new project he is collaborating with Germany's Federal Environment Agency (UBA) in Dessau-Roßlau. Over the past few years, the UBA has developed the emissions model GRETA, which can calculate how high the emissions and pollution levels are for Germany as a whole. Moreover, GRETA can peer into the future and use simulations to determine which measures could be used to reduce the air pollution at specific sites. But even GRETA can profit from Hendrik Elbern's support. "GRETA does very precise work, but she doesn't always get it right," says Ute Dauert, an air-quality assessment expert at the UBA. "Using inverse modelling, Mr Elbern can compare the data generated by GRETA with actual measurements and tell us wherever the two don't match."

Hendrik Elbern has been a part of the REKLIM initiative from the outset, because, in his eyes, air quality and regional climate go hand in hand. Take aerosols for example: These compounds, which are suspended in the air, are directly emitted in some cases, but can also be formed from other gaseous pollutants. Further, they can interact with sunlight to produce warming or cooling effects. And conversely, the climate, through precipitation or typical air currents, can help determine the amount of airborne pollutants in a given region. Accordingly, if there's one thing that Hendrik Elbern knows for sure, it's this: air quality is definitely a REKLIM topic.

IN BRIEF

- **How many pollutants are released into the atmosphere in Germany are assessed on the basis of massive datasets and published in the form of 'emission inventories'.**
- **The estimated levels from the inventories do not always match the actual measured values, because the latter are influenced by transport and local chemical transformations. Mathematical models are now also being used to reconcile these discrepancies.**
- **Since pollution levels can't feasibly be measured everywhere, we will continue to need reliable estimates in order to gauge the level for the country as a whole and all of its regions.**