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Impacts

Reducing air pollution worldwide

IIASA analysis has formed the backbone of European air pollution policy since the 1980s, including the latest agreement which became law in December 2016. Scientists at the institute are now applying their expertise to the urgent air pollution situation in other parts of the world.

Summary

- Air pollution is a global problem causing **5.5-7 million** premature deaths each year. It also causes **environmental impacts** such as damage to crops, natural vegetation, aquatic ecosystems, and biodiversity.
- The IIASA **GAINS model** assesses a variety of pollutants, their sources, and the costs and benefits of a number of interventions, providing an independent resource that policymakers can rely on to make **successful and cost-effective policies**.
- Europe has made drastic improvements in air quality since the 1980s through a series of **policies and treaties informed by IIASA science**, including the Gothenburg Protocol, and the Convention on Long-range Transboundary Air Pollution.
- From 1990 to 2010, Europe has reduced emissions of **sulfur dioxide** by 83%, **nitrogen oxide** by 47% and **particulate matter** by 25%.
- IIASA researchers provided the analysis behind the new European Clean Air policy, which became law in 2016 and aims to **reduce health impacts of pollution by 50%** compared to 1990 levels in 2030.
- Greenhouse gases are also included in GAINS, and the model has been used for climate policy input at global and European levels, including the **EU Climate and Energy Strategy for 2030**.
- The GAINS model has global coverage, including regional versions for **South Asia and China**, which are being used by policymakers to support new policy development.
- Researchers at IIASA are working with policymakers in other regions to tackle **city-level pollution** and other specific issues.

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"IIASA modelling has been essential in supporting the development and adoption of legally binding transboundary air pollution management instruments that are scientifically, technically, and economically sound." - **Thomas Verheye**, Head of Unit on Industrial Emissions, Air Quality & Noise, Directorate-General for Environment, European Commission

Air pollution not only dulls the sunlight and obscures views, it also damages the environment and contributes to major health problems including respiratory and heart disease. An estimated 450,000 people died prematurely from air pollution in Europe in 2013. Worldwide, the World Health Organization (WHO) estimates the number of premature deaths linked to air pollution at 5.5-7 million annually.

Cleaning up the air is a challenging problem because pollution includes many different substances that are released by many different sources, some easier to regulate than others. Pollutants can also interact with each other in the atmosphere and form new, sometimes more harmful, substances. Moreover, polluting gases and small particles travel through the atmosphere with no respect to national boundaries, which means an international approach is necessary.

Europe has been working on air quality since the acid rain crisis in the 1970s. In recent years, air quality has also become an urgent issue in many other regions of the world, particularly around large cities in Asia and Africa. Air pollution is also closely tied to climate change, as the greenhouse gases that cause atmospheric warming are released by many of the same sources and processes as other air pollutants.

Since the 1980s, IIASA research has provided detailed analysis to support policymakers in tackling this complex issue. IIASA scientists have earned the trust of policymakers through their independence from national interests and their ability to provide systematic assessments of the problems, the solutions, the benefits, and the costs.

Research to clear the air

The Greenhouse Gas – Air Pollution Interaction and Synergies (GAINS) model is the key tool that underlies IIASA air quality research. The model was initially designed to assess the air pollution that contributed to acid rain, and has been continually developed and improved over the last 30 years, with additional pollutants, sources, interactions, and information on mitigation policy options and technologies. The model can be used to estimate emissions of multiple pollutants from different sources, and the cost and effectiveness of measures to reduce emissions. It also provides information on the benefits of action, both for the environment and human health. The model takes into account greenhouse gases such as CO_2 and methane that are emitted by many of the same activities as the conventional air pollutants.

GAINS is unique, not only in its analytical capabilities, but also in its accessibility to policymakers and other stakeholders. The tool is available freely online for anyone to access, and each year, IIASA researchers train dozens of experts and policymakers in using the model. Today, over 1,000 researchers and policymakers use the model each year to study air pollution and assess policy options.

Research using the GAINS model has led to findings that have the potential to improve air quality while simultaneously tackling climate change. For example, research published in the journal *Science* in 2012 showed that tackling short-lived greenhouse gases such as methane and black carbon pollution could reduce future global warming by about 0.5°C by 2030, and prevent between 0.7 and 4.6 million premature deaths every year from outdoor air pollution. This research has been taken up by governments as well as the international Clean Air and Climate Coalition, on which IIASA Air Quality and Greenhouse Gases Program Director Markus Amann serves as an advisor.

Supporting effective air pollution policies

European air quality has improved substantially in recent decades, in large part because of effective policies informed by IIASA analysis. And IIASA analysis shows that these policies have also helped Europe avoid increasing pollution and the significant health and environmental impacts that would have come with it.

From 1990 to 2010, Europe managed to reduce population exposure to $PM_{2.5}$, one of the most damaging pollutants to human health, by about 45%. Without policies, estimates show that $PM_{2.5}$ levels would have continued to increase and in 2010 would have been approximately three times higher than in reality. Furthermore, the health impacts of ozone would have been 70% higher. Environmental problems such as acidification would have been 30 times more than severe than today, and eutrophication from nitrogen pollution around three times higher.

IIASA analysis laid the groundwork for a series of air pollution policies in Europe, starting with the Convention on Long-range Transboundary Air Pollution, signed in 1979. The treaty was one of the first successful international agreements on environmental pollution. Since 1995, IIASA has provided the quantitative analysis for the subsequent European air quality policies, including the National Emissions Ceiling Directives from 1996 to 2000, the Gothenburg Protocol revision in 2011 and 2012, and the Thematic Strategy on Air Pollution from 2012-2015, which was used to define the new Clean Air Policy Packages which came into effect in December 2016. If successfully implemented, the new agreement would cut health impacts of air pollution in Europe by 50% in 2030, as well as reducing environmental impacts such as forest damage and biodiversity loss. IIASA research also supported the 2014 European Commission proposal on climate targets, which would reduce EU greenhouse gas emissions by 40% below the 1990 level by 2030. IIASA researchers contributed to an impact assessment which showed the benefits and costs of different policies.

Unlike many research tools, GAINS was designed for policymaking and to be used by policymakers. By listening to what the policymakers need, and continually developing the model based on those needs, IIASA scientists built a tool that was uniquely able to provide the facts to support more stringent air pollution policies. Policymakers have credited the GAINS mode with making the costs and benefits of policies clear and easily understandable, and allowing them to test out different options and understand their consequences.

The global air quality challenge

While much progress has been made in Europe, air pollution remains a major problem in other areas of the world, and is growing worse. In some cities, air pollution is at crisis levels, and urgent action as well as long-term policies will be needed in order to reverse the trend. Rapidly growing cities in Asia and Africa currently experience air pollution levels far beyond WHO guidelines. In Southeast Asia, the WHO estimates that air pollution was linked to 2.6 million premature deaths in 2012.

IIASA has worked with Asian countries to develop versions of the GAINS model that are customized for the region. Currently, GAINS versions are available for China, India, and South Asia. Now researchers are working on applying their research at the city level, identifying actions that local and regional governments can take to reduce extreme levels of pollution while at the same time cutting emissions of greenhouse gases. So far, versions are being developed for Beijing and the surrounding region, Hanoi, Delhi, and others. Researchers customize the model for each city, taking into account the local surroundings, industries, pollution sources, and atmospheric conditions to produce a clear accounting of where the pollution is coming from and how to address it in the most cost-effective way.

As populations around the world grow, and people increasingly move to cities, air pollution is expected to remain a major problem. The success of European policy shows that this challenge is surmountable, and that the benefits of addressing pollution may far outweigh the costs in the long run.

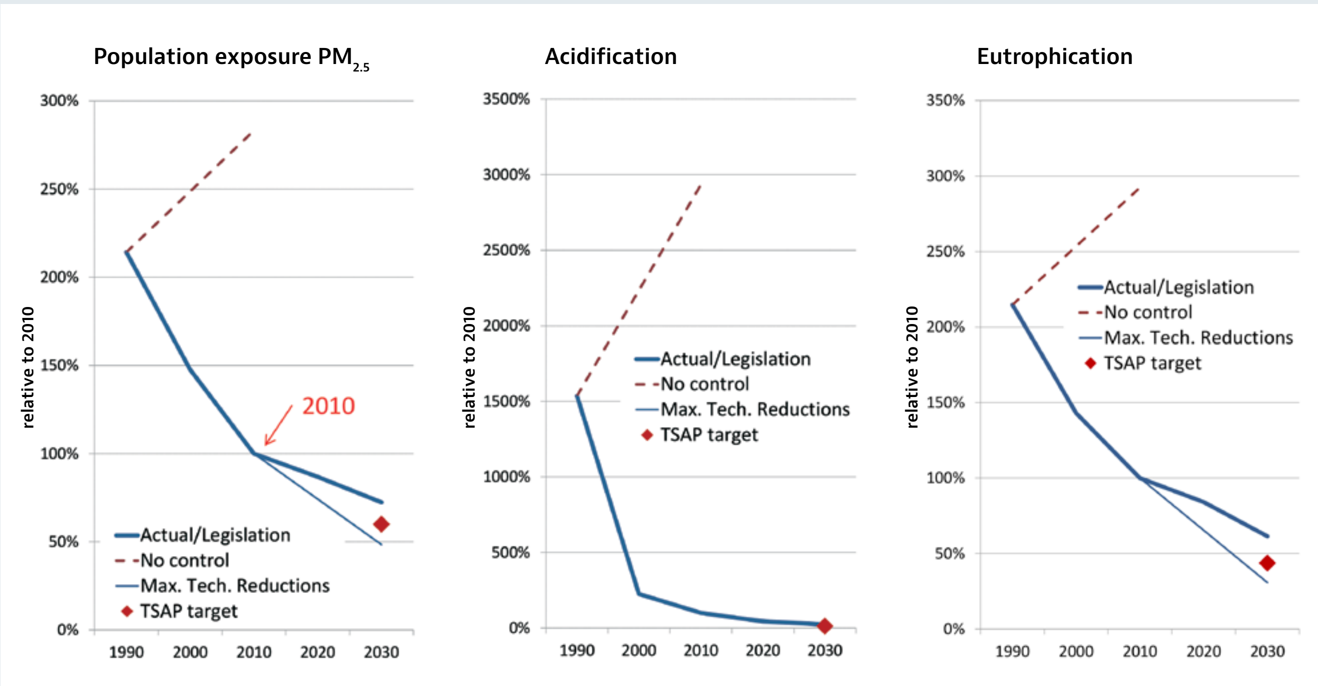
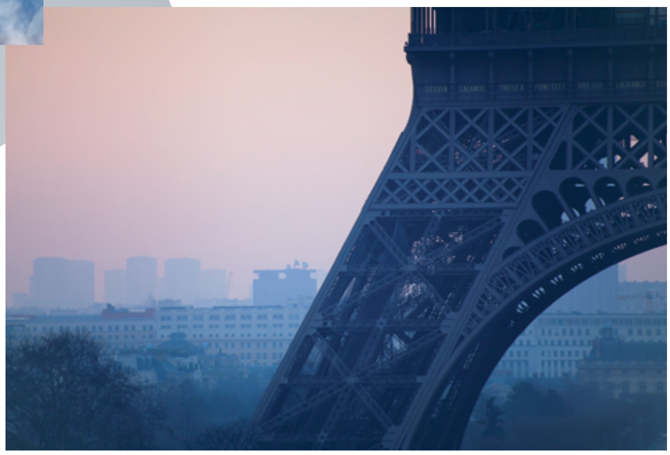


Figure: Trends of population exposure to $PM_{2.5}$, acidification, and eutrophication between 1990 and 2020: A comparison between the actual development and the hypothetical evolution in absence of the policy interventions in Europe.



The culprits

One of the challenges in addressing air pollution is that there are many different substances in air pollution, some released directly and others that form from reactions of other pollutants and natural substances in the atmosphere. The list below highlights just a few of the key pollutants that are included in IIASA analysis.

- **Particulate matter (PM):** Extremely small particles that can be released directly by industry or transportation, or form as a reaction between other chemicals. The GAINS model accounts for two sizes of particulate matter, particles less than 10 and 2.5 microns in diameter (PM_{10} and $PM_{2.5}$), which, in the long run, can cause heart failure and lung damage.
- **Ozone:** A chemical formed by the reaction of sunlight with other pollutants, ozone is another major concern for human health.
- **Sulfur dioxide (SO_2):** A chemical released by industry, SO_2 and other sulfur oxides contribute to acid rain as well as health impacts.
- **Nitrogen dioxide (NO_2):** NO_2 and other nitrogen oxides (NO_x) are released by fossil fuel combustion, as well as agriculture. They threaten biodiversity, contribute to smog, acid rain, and can cause lung damage.
- **Ammonia (NH_3):** Mainly released by agricultural livestock and fertilizer. NH_3 reacts in the atmosphere with SO_2 and NO_x to form small particles ($PM_{2.5}$) that damage human health. Deposition of NH_3 on ground threatens biodiversity, and contributes to acidification.
- **Carbon dioxide (CO_2):** The main cause of climate change, released by fossil fuel combustion, it traps heat in the atmosphere.
- **Short-lived greenhouse gases**, including methane (CH_4), black carbon, and others, contribute to both air pollution and climate change, but stay in the atmosphere for much shorter periods than CO_2.

Further information

Rao S, Klimont Z, Smith SJ, Van Dingenen R, Dentener F, Bouwman L, Riahi K, Amann M, et al. (2017). *Future air pollution in the Shared Socio-economic Pathways*. Global Environmental Change 42: 346-358. **[pure.iiasa.ac.at/13413/]**

Sanderson WC, Striessnig E, Schöpp W, & Amann M (2013). *Effects on well-being of investing in cleaner air in India*. Environmental Science & Technology 47 (23): 13222-13229. **[pure.iiasa.ac.at/10337/]**

Schucht S, Colette A, Rao S, Holland M, Schöpp W, Kolp P, Klimont Z, Bessagnet B, et al. (2015). *Moving towards ambitious climate policies: monetised health benefits from improved air quality could offset mitigation costs in Europe*. Environmental Science & Policy 50: 252 **[pure.iiasa.ac.at/11476/]**

Shindell DT, Kuylenstierna JCI, Vignati E, van Dingenen R, Amann M, Klimont Z, Kupiainen K, & Hoeglund-Isaksson L (2012). *Simultaneously mitigating near-term climate change and improving human health and food security*. Science 335 (6065): 183-189. **[pure.iiasa.ac.at/10016/]**

Xing J, Wang SX, Chatani S, Zhang CY, Wei W, Hao JM, Klimont Z, Cofala J, et al. (2010). *Projections of air pollutant emissions and its impacts on regional air quality in China in 2020*. Atmospheric Chemistry and Physics 10 (11): 26891-26929. **[pure.iiasa.ac.at/9519/]**

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