The Economist INTELLIGENCE UNIT

Climate change and its impact on lung health: a focus on Europe

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About this report

Climate change and its impact on lung health: a focus on Europe is an Economist Intelligence Unit report, sponsored by Chiesi.

Climate change is a health issue with particular effects on respiratory health. This research summarises the direct and indirect evidence that links climate change to lung health and maps out policy priorities to prevent and curb the effects of climate change on lung health.

This independent report is the result of multiple research phases. First, we conducted a pragmatic literature review of the evidence and policy frameworks across the academic and grey literature to develop an initial set of policy priorities. Second, we convened an advisory board on May 19, 2021, drawn from the academic, climate change, environment and healthcare sectors, whose advice shaped the priorities of the study and the content of the report. Third, we conducted 12 interviews with respiratory clinicians, academics, policymakers and climate change and health experts to obtain an in-depth view of the issues involved. Finally, supporting the research, and feeding into this publication, has been substantial desk research.

Our thanks are due to the following for their time and contribution (listed alphabetically by surname):

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Note on references: We have used "Ibid" for citing a reference that appears in a previous footnote. Websites were accessed on 29 July 2021.

September 2021

Executive summary

Global warming impacts respiratory health in many ways: it will increase the risk of extreme climate events, such as extreme temperatures and storms,[1] which can increase the risk of other environmental incidents such as forest fires and dust storms. It will affect levels of circulating aeroallergens by extending the pollen season, and it will promote conditions that result in poor air quality.[2] Together these environmental factors will simultaneously worsen the severity of pre-existing respiratory diseases and elicit onsets of respiratory conditions in previously healthy individuals.[3]

The World Health Organisation (WHO) has warned that climate change poses potentially the greatest threat to global health in the 21st century.[4]

In an attempt to reduce the threats of global warming, 189 countries have signed the landmark 2015 Paris Agreement to limit global warming to "well below" 2°C and to attempt to limit it to 1.5°C.[5] However, there is increasing evidence that the actions taken by government are not enough[6] and that tougher action is needed within the next decade,[7] including an end to the development of fossil fuel reserves.[8]

Global warming is caused by an increase in the emission of greenhouse gases, which include carbon dioxide (CO_2) but also include methane, nitrous oxide, chlorofluorocarbons and water vapour.[9]

Our research suggests that those most at risk of declining lung health as a result of climate change are those with chronic respiratory diseases, people over age 65, children as their lungs are still developing, lower socioeconomic groups because they are more likely to live in areas with high levels of air pollution and outdoor workers.

How the climate impacts respiratory health

Extreme temperatures

Deaths attributable to heatwaves are expected to rise significantly in Europe this century.[10] In the heatwave of summer 2003, there were more than 70,000 excess deaths in

[1] Stott P, Stone D, Allen M. Human contribution to the European heatwave of 2003. Nature. 2004;432:610-4.
[2] Doherty RM, Heal MR, O'Connor FM. Climate change impacts on human health over Europe through its effect on air quality. Environmental Health. 2017;16(Suppl 1):118.
[3] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[4] WHO. Health, environment and climate change. Report by the director-general. 9 Apr 2018. Available from: https://apps.who.int/iris/bitstream/handle/10665/276332/A71_10-en.pdf
[5] UN. The climate crisis: a race we can win. Available from: https://www.un.org/en/un75/climate-crisis-race-we-can-win
[6] World Meteorological Organization. WMO climate statement: past 4 years warmest on record. 29 Nov 2018. Available from: https://public.wmo.int/en/media/press-release/wmo-climate-statement-past-4-years-warmest-record
[7] World Meteorological Organization. The state of the global climate 2020: unpacking the indicators. 20 Apr 2021. Available from: https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate
[8] International Energy Agency. Net zero by 2050. A roadmap for the global energy sector. Paris: International Energy Agency; May 2021. Available from: https://www.iea.org/reports/net-zero-by-2050
[9] American Chemical Society. Which gases are greenhouse gases? Available from: https://www.acs.org/content/acs/en/climatescience/greenhousegases/whichgases.html
[10] Kendrovski V, Baccini M, Martinez G et al. Quantifying projected heat mortality impacts under 21st-century warming conditions for selected European countries. Int. J. Environ. Res. Public Health. 2017;14:729. Astrom C et al. Vulnerability reduction needed to maintain current burdens of heat-related mortality in a changing climate-magnitude and determinants. Int J Environ Res Public Health. 2017;14:741.

12 European countries, and such high summer temperatures are expected to be the norm by the middle of the century in Europe.[11,12] Europe and the eastern Mediterranean are the regions of the world most vulnerable to the health impacts of heat.[13]

Increased pollen

Climate change is having a significant impact on the production and dispersal of pollen across Europe.[14,15] Rising temperatures and CO_2 levels are expanding the geographic range of allergenic plants (including ragweed, considered to produce one of the most potent aeroallergens[16]), are extending the season over which plants can grow and release pollen, and are increasing the concentration of pollen that is produced.[17]

People with pollen allergies experience hay fever (allergic rhinitis) during the pollen season, but high pollen concentrations can have more serious implications for their respiratory health if they have asthma. Most pollen is normally caught in the upper airways, but storms and pollution can cause pollen grains to burst, releasing allergen microparticles within the pollen which can get into the lower airways and cause exacerbations.[18]

Extreme weather events

Rising temperatures also provoke extreme weather events, such as wildfires, dust storms and thunderstorms. There is an association among the onset of a thunderstorm, a rise in pollen concentration and the onset of asthma epidemics.[19] Particulate matter (PM) from wildfires can travel up to 1,000 km and thus pose a threat to respiratory health over a wide area.[20] Desert dust is another form of particulate matter, which can travel much farther still. As well as particulates, dust storms can carry fungal spores, viruses and pollen.[21]

Heavy rainfall and more frequent storms brought about by climate change will cause rising sea levels, increased flooding and more damp buildings, conditions that promote the growth of and exposure to mould spores.[22,23,24] The link between moulds and asthma and rhinitis is well documented.[25]

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[11] Robine JM, Cheung SL, Le Roy S et al. Report on excess mortality in Europe during summer 2003. EU Community Action Programme for Public Health, grant agreement 2005114. Montpellier: 2003 Heat Wave Project; 2007.
[12] D'Amato G, Pawankar R, Vitale C et al. Climate change and air pollution: effects on respiratory allergy. Allergy Asthma Immunol Res. 2016;8(5):391-5.
[13] Watts N, Amann M, Arnell N et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. Lancet. 2021;397(10269):129-70.
[14] Rice MB, Thurston GD, Balmes JR et al. Climate change: a global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
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[16] Rasmussen K, Thyrring J, Muscarella R et al. Climate-change-induced range shifts of three allergenic ragweeds (Ambrosia l.) in Europe and their potential impact on human health. PeerJ. 2017;5:e3104.
[17] Barnes CS. Impact of climate change on pollen and respiratory disease. Curr Allergy Asthma Rep. 2018;18(11):59.
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[19] Ibid.
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[21] D'Amato G, Holgate ST, Pawankar R et al. Meteorological conditions, climate change, new emerging factors, and asthma and related allergic disorders. A statement of the World Allergy Organization. World Allergy Organ J. 2015;8(1):25.
[22] D'Amato G, Chong-Neto HJ, Monge Ortega OP et al. The effects of climate change on respiratory allergy and asthma induced by pollen and mold allergens. Allergy. 2020;75(9):2219-28.
[23] Demain JG. Climate change and the impact on respiratory and allergic disease: 2018. Curr Allergy Asthma Rep. 2018;18(4):22.
[24] European Environment Agency. Floods and health. 2021. Available from: https://www.eea.europa.eu/data-and-maps/indicators/floods-and-health-1/assessment
[25] Mendell MJ, Mirer AG, Cheung K et al. Respiratory and allergic health effects of dampness, mold, and dampness-related agents: a review of the epidemiologic evidence. Environ Health Perspect. 2011;119:748-56.

The link between air pollution and climate change

Much of the responsibility for global warming lies in the release of greenhouse gases—particularly CO_2—from burning fossil fuels, which also causes air pollution.

In 2018, the UN formally recognized both outdoor and indoor pollution as risk factors for non-communicable diseases, alongside factors such as smoking, poor diet, lack of exercise and alcohol.[26]

Emissions that impact health include nitrogen dioxide (NO_2), particulate matter, ozone and methane. Ground-level ozone is formed through atmospheric reactions between nitrogen oxides (NOx), volatile organic compounds and methane in the presence of sunlight, so it often increases at higher temperatures.[27,28]

Short-term exposure to elevated levels of air pollution can exacerbate asthma, affect lung function and increase respiratory and cardiovascular hospital admissions and deaths.[29] Exposure to air pollution over a longer term reduces life expectancy, mainly due to cardiovascular and respiratory causes and lung cancer.[30]

Long-term exposure to fine particulate matter ($PM_{2.5}$) was responsible for 417,000 premature deaths in Europe in 2018, NO_2 for 55,000 and ozone for 20,600.[31] Between 2009 and 2018, premature deaths from $PM_{2.5}$ fell by 13% and those from NO_2 were reduced by more than half, but those from ozone increased by 20%.[32]

While outdoor air pollution is claiming increasing attention, very little attention is given to indoor air quality, which is affected by both the quality of the air outside and the pollutants in the building itself.[33]

Pollutants in indoor air can irritate lungs and exacerbate asthma symptoms, and indoor air pollution has been linked to asthma, wheezing, conjunctivitis, dermatitis and eczema in children.[34] Potential sources of indoor pollutants include heating sources, particularly wood burning stoves, and natural gas leakage from cookers and gas fires; volatile organic compounds from cleaning products, air fresheners and household furnishings; and candles, dust mites and pet dander.[35] Smoking also remains a leading contributor of indoor air pollution.[36]

The structure of buildings can also contribute to indoor air pollution. Old buildings are more likely to be subject to damp problems, which

[26] UN. Political declaration of the third high-level meeting of the General Assembly on the prevention and control of non-communicable diseases. Time to deliver: accelerating our response to address noncommunicable diseases for the health and well-being of present and future generations. New York: United Nations; 2018. Available from: https://ncdalliance.org/sites/default/files/Political_Declaration_final_text_0.pdf
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[28] Climate and Clean Air Coalition. Methane. https://www.ccacoalition.org/en/slcps/methane
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[30] Ibid.
[31] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: Publications Office of the European Union; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[32] Ibid.
[33] Mendoza DL, Benney TM, Boll S. Long-term analysis of the relationships between indoor and outdoor fine particulate pollution: a case study using research grade sensors. Sci Total Environ. 2021;776:145778.
[34] Royal College of Paediatrics and Child Health. The inside story: health effects of indoor air quality on children and young people. Jan 2020. Available from: https://www.rcpch.ac.uk/resources/inside-story-health-effects-indoor-air-quality-children-young-people
[35] Ibid.
[36] San Diego State University. Smoking out sources of in-home air pollution: a new study finds that cigarette and marijuana smoking, as well as candles, cleaning products and frying food, all harm a household's air quality. ScienceDaily, 18 May 2017.

are linked to increased risk of mould and dust mites, which can exacerbate asthma,[37,38] but new buildings are not without problems.[39] Climate change mitigation efforts mean building regulations place emphasis on the energy efficiency of buildings, but they contain few specific standards for air quality.[40] As a result, they are often highly insulated with well-fitting windows, so they have little airflow, meaning pollutants get trapped inside.

What policies are needed?

Solutions must be integrated and multifaceted because climate change is driven by a complex web of interrelated factors. Our analysis and insight from our advisory board and interviewees illustrate that, for climate change action to be successful, the approach needs to be holistic, involving all the key stakeholders and adopting a common goal to improve public health.

Air pollutants and greenhouse gases must be seen as a combined problem, and action must consider all emissions and health consequences. All stakeholders must be engaged in the design of policy, and emissions cuts must be demanded from all sectors.

Europe aims to be the first climate-neutral continent by 2050 by moving to an economy with net-zero greenhouse gas emissions. The EU has also put forward a plan to cut greenhouse gas emissions to 55% of 1990 levels by 2030.[41] However, many countries are falling short of their ambition and implementation of their climate change action plans, and there are increasing demands from climate change activists, the health sector and the public for stronger action, with some even taking national governments to court to force their hands.[42,43,44]

While Europe cannot prevent global warming alone, it is important for Europe to be seen to act on climate change by reducing emissions as quickly and as effectively as possible and by going beyond existing international standards and targets.

Our research, advisory board discussions and interviews highlight the opportunities and policy priorities that exist for some key stakeholder groups.

[37] Sharpe RA, Thornton CR, Nikolaou V et al. Fuel poverty increases risk of mould contamination, regardless of adult risk perception and ventilation in social housing properties. Environ Int. 2015;79:115-29.
[38] Simoni M, Lombardi E, Berti G et al. Mould/dampness exposure at home is associated with respiratory disorders in Italian children and adolescents: the SIDRIA-2 study. Occup Environ Med. 2005;62(9):616-22.
[39] Royal College of Paediatrics and Child Health. The inside story: health effects of indoor air quality on children and young people. Jan 2020. Available from: https://www.rcpch.ac.uk/resources/inside-story-health-effects-indoor-air-quality-children-young-people
[40] Ibid.
[41] European Commission. 2030 climate target plan. Available from: https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en
[42] Netherlands climate change: court orders bigger cuts in emissions. BBC News, 20 Dec 2019.
[43] Connolly K. 'Historic' German ruling says climate goals not tough enough. The Guardian, 29 Apr 2021.
[44] El Gharib S. France found guilty of climate inaction in 'historic victory' for activists. Global Citizen, 3 Feb 2021.

Summary of EIU policy priorities on climate change and lung health

European and national level

Priority areas

- **End burning of fossil fuels**
- **Make improving public health the central goal in climate change policies**
- **Involve all relevant stakeholders in climate change policies**

- Speed up progress on climate change beyond existing targets through legislation and international cooperation
- Act to reduce greenhouse gases and emissions by fostering innovation across all sectors
- Prioritise tackling methane as well as hydrofluorocarbons (encouraging the use of alternatives with a low global warming potential)
- Encourage use of electrical power to support the ultimate switch to clean renewable sources
- Improve interconnectivity of national electricity grids to maximise use of clean renewables
- Remove fossil fuel subsidies and extend carbon pricing to move away from fossil fuels
- Move way from burning wood and biomass as these are associated with high levels of particulate pollution
- Invest in clean energy, green innovation and technology
- Be a leader on climate change issues on the world stage

Environmental and local level

Priority areas

- **Focus on improving air quality, particularly in urban areas where most people live**
- **Ensure air quality data are easily accessible**
- **Promote active transport and public transport powered by clean energy**

- Design cities and transport policies that discourage the use of vehicles with combustion engines
- Issue standardised warnings for high levels of air pollutants and aeroallergens
- Consider air quality metrics alongside energy efficiency in construction/renovation of buildings
- Provide green and traffic-free spaces
- Reduce health inequalities by introducing measures to tackle climate change

Climate change and lung health

Healthcare sector

Priority areas

- **Improve education of healthcare professionals on the impact of air quality and climate change on lung health**
- **Focus attention on high-risk and vulnerable people (older, those living with respiratory conditions)**

- Use health professionals as trusted members of communities to raise awareness of the effects of climate change and air pollution on lung health
- Conduct research to increase our understanding of the impact of climate change and air quality on lung health
- Act as an exemplar in reducing emissions and moving to net-zero carbon emissions to encourage other sectors to follow
- Healthcare professionals are trusted so can help effect national/international action on climate change

Public, civil society and media

Priority area

- **Lobby political representatives to act on climate change locally and at the EU level**

- Bring in measures to boost awareness and action by the public (eg, citizen science approaches using personal air quality monitors can help engage the public)
- Make messages easy to understand for clearer messaging by media
- Grass roots champions and legal challenges can encourage politicians to act on climate change

Conclusion

There is evidence that emissions linked to global warming have an adverse impact on respiratory health, in particular emissions from the combustion of fossil fuels and biomass by power stations, industry, homes and vehicles. Awareness of this danger is increasing among the heath sector and the European general public, and as it continues to grow, there are demands for tougher action.

Individuals cannot stop climate change; the cuts to emissions that they can make are limited. Only politicians and public authorities can put in place the policies and frameworks to change systems, to make the big cuts to emissions that are needed.

Increasing awareness among the health sector and the general public of the need for urgent action on climate change is the path to achieving it, by putting pressure on politicians to act.

Section 1: Climate change and its impact on lung health

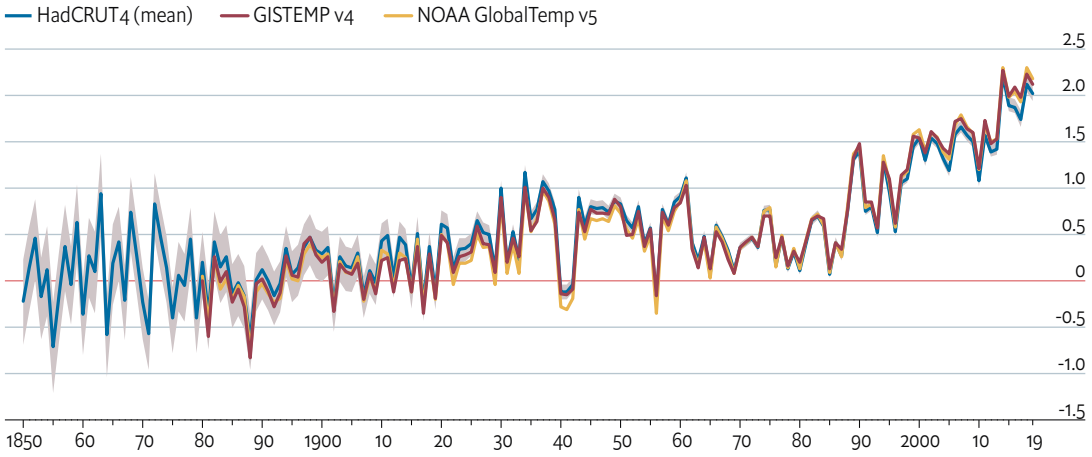
1.1 What is climate change?

Climate change affects the health of the planet and its inhabitants. This report focuses on the impact of climate change on lung health, based on available evidence and insight from experts, and concludes with policy recommendations on what more needs to be done.

Global temperatures have stayed fairly constant over the past few thousand years, but since 1880, the average global temperature has increased by more than 1°C. The pace of that rise has accelerated in recent times, with two-thirds of that warming occurring since 1975, at a rate of roughly 0.15-0.20°C per decade (Figure 1).[45,46,47]

This warming has been caused by an increase in the emission of greenhouse gases that trap heat.[48] These gases are largely made up of carbon dioxide (CO_2), but also include methane, nitrous oxide (N^2O), chlorofluorocarbons and water vapour.[49] The more greenhouse gases are concentrated in the atmosphere, the more heat is locked in.

Figure 1: European average temperature relative to a 'pre-industrial' period between 1850 and 1899
(data from different monitoring stations indicated by different colours)



Source: European Environment Agency. Global and European temperatures. https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-10/assessment.

[45] NASA Earth Observatory. World of change: global temperatures. https://earthobservatory.nasa.gov/world-of-change/global-temperatures
[46] Nunez C. Causes and effects of climate change. National Geographic, 22 Jan 2019.
[47] European Environment Agency. Global and European temperatures. https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-10/assessment
[48] Nunez C. Causes and effects of climate change. National Geographic, 22 Jan 2019.
[49] American Chemical Society. Which gases are greenhouse gases? https://www.acs.org/content/acs/en/climatescience/greenhousegases/whichgases.html

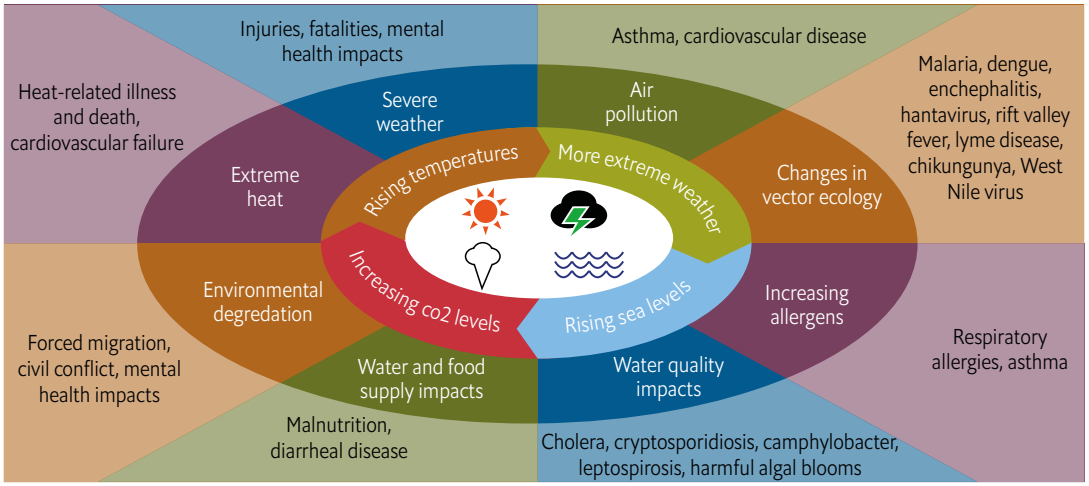
Since the industrial revolution, the burning of fossil fuels, changes in agricultural practices, mechanisation, technological advancements and a rising population have all led to greater emission of greenhouse gases, particularly over the past few decades. Since the industrial revolution, the amount of CO_2 in the atmosphere has increased by around 50%.[50]

Global warming has an impact on the climate, causing more severe and prolonged heatwaves, temperature variability, poor air quality, forest fires, droughts and floods, all of which have consequences for human health, including respiratory health (Figure 2). Changes in climate and air quality have a significant impact on morbidity and mortality from respiratory diseases.[51]

In an attempt to reduce the threats of global warming, the landmark 2015 Paris Agreement on climate change saw 189 countries commit to limit global warming to "well below" 2°C, and to attempt to limit it to 1.5°C.[52] However, the World Meteorological Organisation (WMO) warned in 2018 that, based on current trends in greenhouse gas emissions, temperatures could rise by 3°C to 5°C by 2100, so more action is needed.[53]

"Stabilising global mean temperature at 1.5°C to 2°C above pre-industrial levels by the end of this century will require an ambitious reduction of greenhouse gas emissions, which must begin to occur during this decade," Petteri Taalas, secretary-general of the WMO, said in April 2021.[54]

Figure 2: Impacts of climate change on human health



Source: Ebi KL, Hess JJ, Watkiss P. Health Risks and Costs of Climate Variability and Change. Injury Prevention and Environmental Health. 3rd edition. 2017 Oct 27. Chapter 8. Available from: https://www.ncbi.nlm.nih.gov/books/NBK525226/ doi: 10.1596/978-1-4648-0522-6_ch8.

[50] Betts R. Carbon dioxide (CO_2) in the atmosphere is now reaching levels 50% higher than when humanity began large-scale burning of fossil fuels during the industrial revolution. Carbon Brief, 21 Mar 2021.
[51] D'Amato G, Pawankar R, Vitale C et al. Climate change and air pollution: effects on respiratory allergy. Allergy Asthma Immunol Res. 2016;8(5):391-5.
[52] UN. The climate crisis: a race we can win. Available from: https://www.un.org/en/un75/climate-crisis-race-we-can-win
[53] World Meteorological Organization. WMO climate statement: past 4 years warmest on record. 29 Nov 2018. Available from: https://public.wmo.int/en/media/press-release/wmo-climate-statement-past-4-years-warmest-record
[54] World Meteorological Organization. The state of the global climate 2020: unpacking the indicators. 20 Apr 2021. Available from: https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate

In May 2021, the world's richest nations signalled they are prepared to act. G7 (Group of Seven largest advanced economies) environment ministers issued a communiqué saying they had agreed to deliver climate targets in line with limiting the rise in global temperatures to 1.5˚C and to stop direct funding of coal-fired power stations in poorer nations by the end of 2021.[55]

The ministers are believed to have been heavily influenced by a recent report from the International Energy Agency. The report says there can be no further coal, oil or gas development if the world wants to reach net-zero emissions by the middle of the century and have a chance of limiting temperature rises to 1.5˚C.[56]

1.2 How climate change impacts health and respiratory health

The WHO has warned that climate change poses potentially the greatest threat to global health in the 21st century.[57]

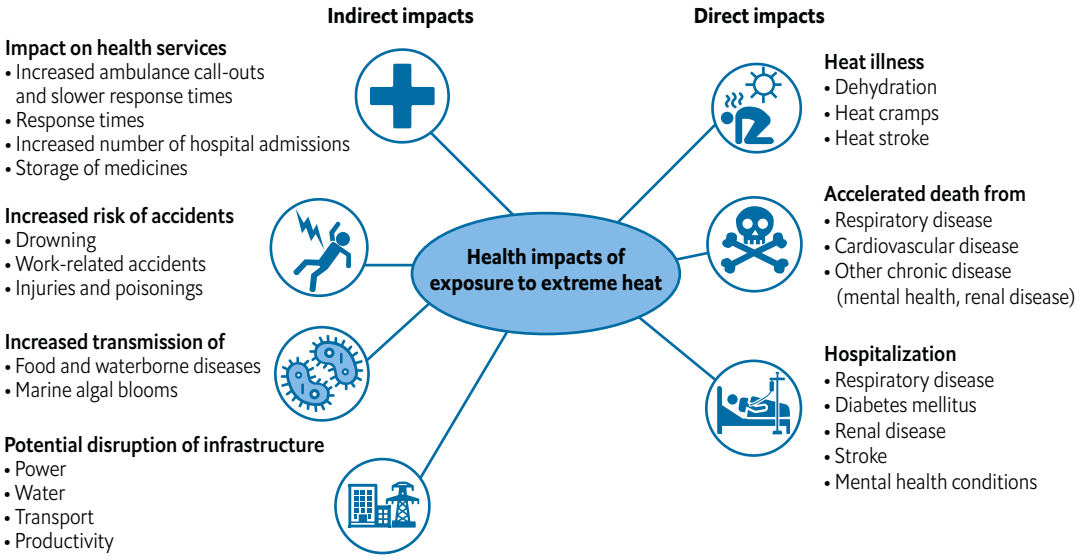
Altered weather patterns and increased temperatures that will result from climate change will affect the distribution, quality and quantity of water, impact on agriculture and food supplies, damage critical infrastructure such as hospitals, and increase political tensions between countries.[58,59] This will also impact health.

Global warming will increase the risk of food and waterborne diseases, and it will allow disease-carrying insects such as ticks, mosquitoes and sandflies to thrive in more regions of the world, putting more people at risk of vector-borne diseases such as malaria and dengue.[60,61] During more frequent heatwaves, people will be at increased risk of heat-related illnesses such as heat stroke and exacerbations of and deterioration from chronic conditions such as cardiovascular and respiratory diseases (Figure 3).[62]

Global warming impacts respiratory health in many specific ways (Figure 4). It will increase the risk of extreme climate events such as extreme temperatures and storms,[63] which can increase the risk of other environmental incidents such as forest fires and dust storms. It will affect levels of circulating aeroallergens by extending the pollen season, and it will

[55] G7 Climate and Environment: Ministers' Communiqué. Joint commitments. 21 May 2021. Available from: https://www.g7uk.org/g7-climate-and-environment-ministers-communique/
[56] International Energy Agency. Net zero by 2050. A roadmap for the global energy sector. Paris: International Energy Agency; May 2021. Available from: https://www.iea.org/reports/net-zero-by-2050
[57] WHO. Health, environment and climate change. Report by the director-general. 9 Apr 2018. Available from: https://apps.who.int/iris/bitstream/handle/10665/276332/A71_10-en.pdf
[58] UN. UN world water development report 2020: water and climate change. 21 Mar 2020. Available from: https://www.unwater.org/world-water-development-report-2020-water-and-climate-change/
[59] WHO. Health, environment and climate change. Report by the director-general. 9 Apr 2018. Available from: https://apps.who.int/iris/bitstream/handle/10665/276332/A71_10-en.pdf
[60] European Environment Agency. Climate change, impacts and vulnerability in Europe 2016. Luxembourg: Publications Office of the European Union; 2017. Available from: https://www.eea.europa.eu/publications/climate-change-impacts-and-vulnerability-2016
[61] UN Framework Convention on Climate Change. Climate change impacts human health. 2017. Available from: https://unfccc.int/news/climate-change-impacts-human-health
[62] WHO. Heat and health. 2018. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health
[63] Stott P, Stone D, Allen M. Human contribution to the European heatwave of 2003. Nature 2004;432:610-4.

Figure 3: Indirect and direct impacts of exposure to extreme heat as a result of climate change on health



Source: WHO; https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health.

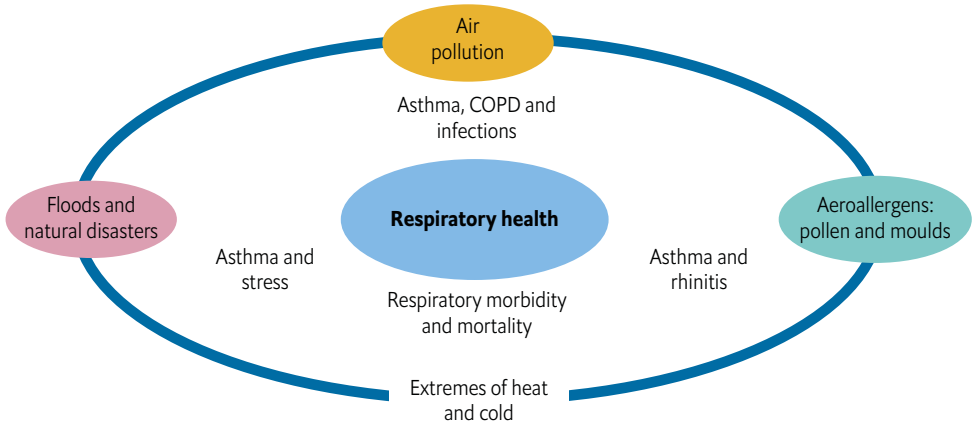
promote conditions that result in poor air quality.[64] Together these environmental factors will simultaneously worsen the severity of pre-existing respiratory diseases and elicit onsets of respiratory conditions in previously healthy individuals.[65]

Many respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD), are triggered by environmental factors, explained Professor Frank Kelly, Battcock Chair in Community Health and Policy, Faculty of Medicine, School of Public Health, Imperial College London, UK. "Exacerbations are triggered by increases in temperature in some people and by decreases in temperature in others," he said. "Poor air quality appears to be a trigger for most people."

Global warming and fluctuating temperatures can also increase the incidence and severity of respiratory infections,[66] he added, but most importantly it can impact circulating seasonal aeroallergens.

[64] Doherty RM, Heal MR, O'Connor FM. Climate change impacts on human health over Europe through its effect on air quality. Environmental Health 2017;16(Suppl 1):118.
[65] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[66] Mirsaeidi M, Motahari H, Taghizadeh Khamesi M et al. Climate change and respiratory infections. Ann Am Thorac Soc. 2016;13(8):1223-30.

Figure 4: Relationship between climate change and respiratory health



Source: D'Amato, G., Cecchi, L., D'Amato, M., Annesi-Maesano, I. Climate Change and Respiratory Disease. European Respiratory Review Jun 2014, 23 (132) 161-169.

"If the temperature increases, what we find is that the trees and plants will respond by producing their pollen earlier in the season, so you get an extended pollen season. That's clearly not good for respiratory disease as it can provoke exacerbations in susceptible individuals."

There is also some evidence that the allergenicity of pollen itself can become worse under higher CO_2 concentrations and under higher temperatures, he added.[67] "So without increasing the pollen load, pollen may be more dangerous because it's allergenicity has changed."

Fossil fuel combustion is the biggest source of greenhouse gas emissions.[68] As well as contributing to global warming, this combustion is also responsible for a large amount of air pollution, which has been linked to the development and exacerbation of respiratory diseases, including asthma, COPD and lung cancer. Experts we spoke to and the advisory board agreed, that reducing fossil fuels combustion must be a priority and that it is the most important action that can be taken against climate change.

"The quality of the air that you breathe has an impact on your lungs," said Professor Kelly. "If you have a respiratory condition, you see the effects pretty quickly, but if you're healthy, long-term exposure to air pollutants will lead to some respiratory outcome.

"Climate change and air pollution are bedfellows," he added. "If you address one, you're really addressing the other as well, and that's why it's a win-win situation for the planet, if we reduce and eventually eliminate fossil fuel use."

[67] El Kelish A, Zhao F, Heller W et al. Ragweed (Ambrosia artemisiifolia) pollen allergenicity: SuperSAGE transcriptomic analysis upon elevated CO_2 and drought stress. BMC Plant Biol. 2014;14:176.
[68] Watts N, Amann M, Arnell N et al. The 2020 report of the Lancet Countdown on health and climate change: responding to converging crises. Lancet. 2021;397(10269):129-70.

1.2.1 Who is at risk and the burden of respiratory diseases in Europe

As part of this analysis, it is important to understand who may be at the highest risk when it comes to the impact of climate change on respiratory health.

Based on our analysis and insight from our advisory board and interviews, those at risk include:

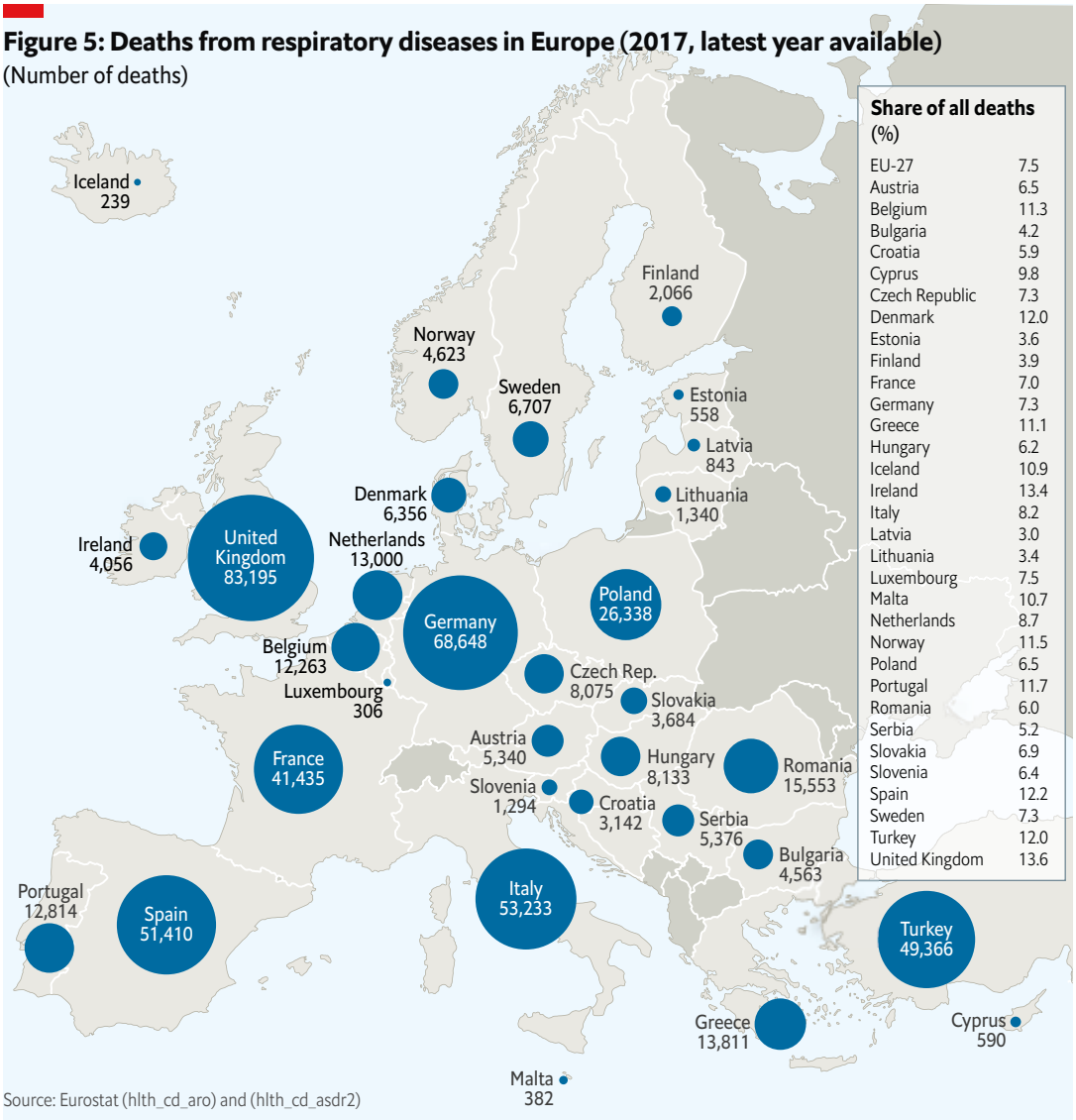
- people over age 65
- children as their lungs are still developing
- outdoor workers and those exercising outdoors due to increased exposure
- individuals in lower socioeconomic groups, who typically have poorer overall health outcomes and are more likely to live in poorer quality housing, in “heat islands” and in areas with greater air pollution
- people living with underlying health conditions, especially respiratory diseases

People living with respiratory conditions are a special risk group because their lungs are already compromised. Such individuals could be identified and targeted by healthcare systems and policymakers to prevent exacerbations. The prevalence of chronic respiratory diseases is highest in high-income countries.[69]

Respiratory system diseases are responsible for 7.5% of all deaths in the EU-27, according to the latest Eurostat statistics.[70] But the proportions vary by country. In 2017, the proportion of deaths attributed to respiratory diseases was highest in Ireland (at 13.4%), and these diseases accounted for at least one in ten deaths in Spain, Denmark, Portugal, Belgium and Greece, as well as in several non-EU countries including the United Kingdom (where it was 13.6%), Turkey, Norway and Iceland (Figure 5).[71]

[69] Soriano JB, Kendrick PJ, Paulson KR et al. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Respir Med. 2020;8(6):585-96.
[70] Eurostat. Deaths from diseases of the respiratory system. 2020.
https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Respiratory_diseases_statistics#Deaths_from_diseases_of_the_respiratory_system
[71] Ibid.

Figure 5: Deaths from respiratory diseases in Europe (2017, latest year available)
(Number of deaths)



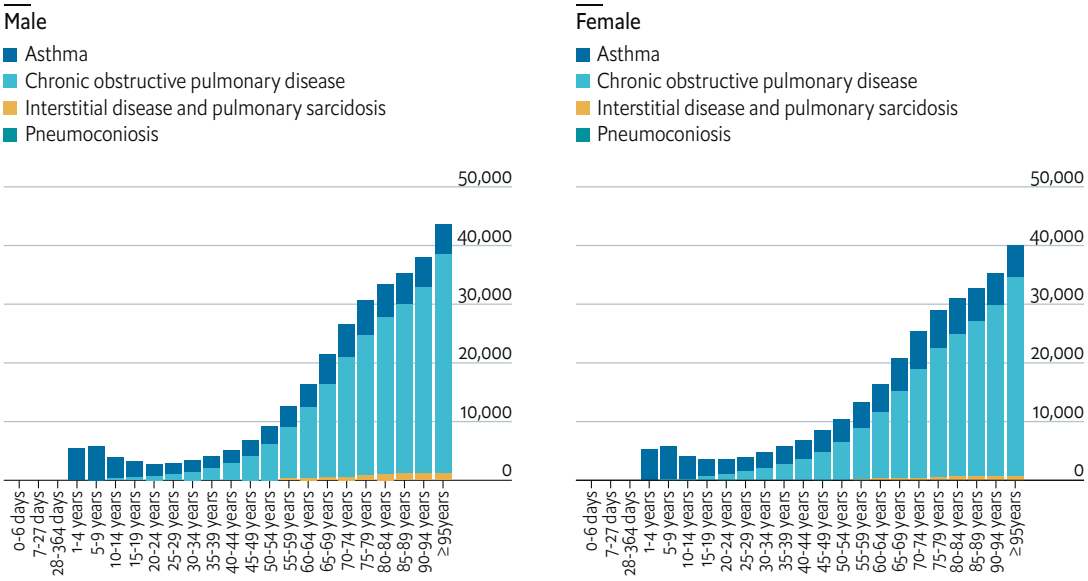
Source: Eurostat (hlth_cd_aro) and (hlth_cd_asdr2)

The prevalence of respiratory disease, and deaths from them, increases dramatically with age (Figure 6).[72] In the EU-27, the standardised death rate from respiratory diseases for those aged 65 years and over was 38 times higher than for those aged less than 65 years.[73]

Generally, a higher proportion of men than women in Europe die from diseases of the respiratory system, although in 2017 the rate was higher in women in Iceland, Ireland, Denmark, Sweden, United Kingdom, Norway, Lichtenstein and Greece. [74]

[72] Soriano JB, Kendrick PJ, Paulson KR et al. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Respir Med. 2020;8(6):585-96.
[73] Eurostat. Deaths from diseases of the respiratory system. 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=respiratory_diseases_statistics#deaths_from_diseases_of_the_respiratory_system
[74] Ibid.

Figure 6: Global age-sex-specific prevalence of chronic respiratory diseases by disease category in 2017 (published June 2020)



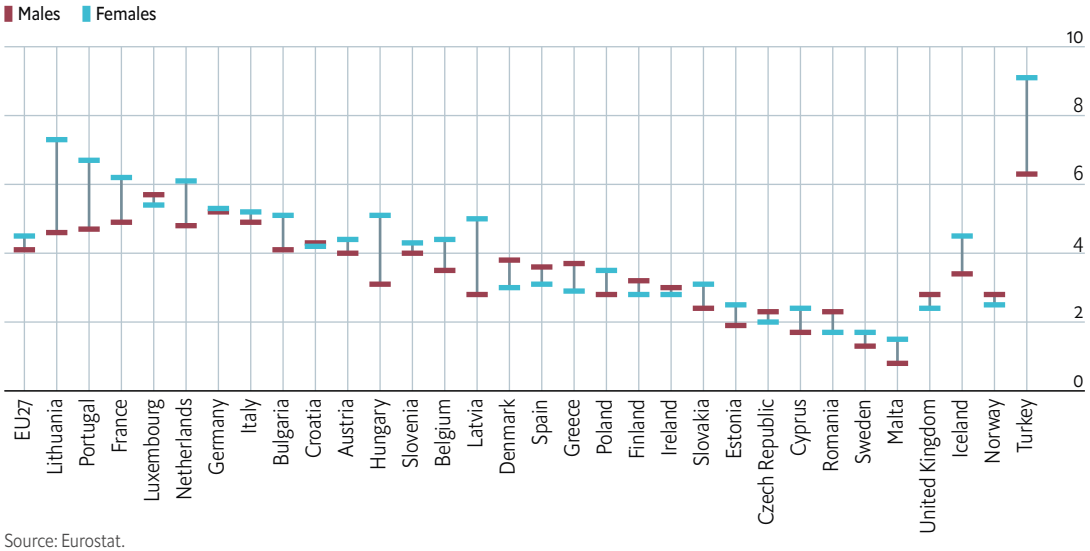
Source: Soriano, Joan B., Kendrick, Parkes J., Paulson, Katherine R., Gupta, Vinay, Shariful Islam, Sheikh, Vos, Theo, Rahman, Muhammad and GBD Chronic Respiratory Disease Collaborators et al 2020, Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017, The Lancet Respiratory Medicine, vol. 8, no. 6, pp. 585-596, https: //www.thelancet.com/journals/lanres/article/PIIS2213-2600(20)30105-3/fulltext.

A survey sheds further light on prevalence in Europe. The European health interview survey, which was conducted between 2013 and 2015 of people aged 15 years and over, asked respondents to self-report respiratory diseases. The survey found that in 2014, 4.3% of this EU-27 population stated they had some form of chronic lower respiratory disease (other than asthma) diagnosed by a doctor, such as chronic bronchitis, emphysema and other COPDs (Figure 7).[75] Meanwhile, 5.4% reported that they suffered from asthma (Figure 8). Asthma may result from a range of triggers, including pollution, tobacco smoke, solvents, pollen, cold air or strenuous exercise.[76] Again, there were dramatic variations among countries for prevalence of both self-reported chronic lower respiratory disease and asthma.[77]

[75] Eurostat. Deaths from diseases of the respiratory system. 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=respiratory_diseases_statistics#deaths_from_diseases_of_the_respiratory_system
[76] Ibid.
[77] Ibid.

Figure 7: Share of the population in Europe reporting chronic lower respiratory disease (excluding asthma), 2014 (latest year)

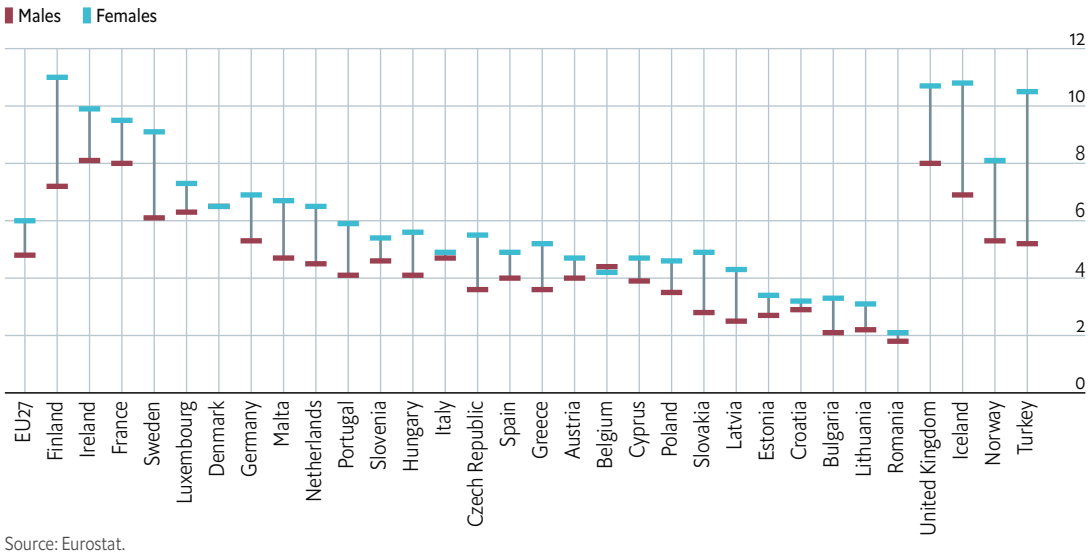
(%)



Source: Eurostat.

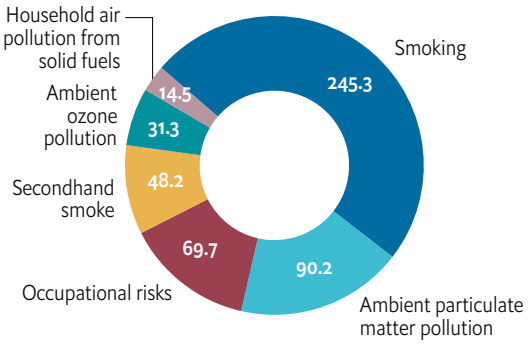
Figure 8: Share of the population in Europe reporting asthma, 2014 (latest year)

(%)



Source: Eurostat.

Figure 9: Chronic respiratory disease-attributable disability life year (DALY) rates by risk factor across central Europe, eastern Europe, and central Asia, 2017
(DALYs per 100,000; age-standardised)



Source: Soriano, Joan B., Kendrick, Parkes J., Paulson, Katherine R., Gupta, Vinay, Shariful Islam, Sheikh, Vos, Theo, Rahman, Muhammad and GBD Chronic Respiratory Disease Collaborators et al 2020, Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017, The Lancet Respiratory Medicine, vol. 8, no. 6, pp. 585-596, https://www.thelancet.com/journals/lanres/article/PIIS2213-2600(20)30105-3/fulltext.

Figure 9 shows the contribution of various factors to chronic respiratory diseases in 2017. As more people quit smoking and occupational risks are reduced in Europe, the contribution of air pollution (both outdoor and indoor) and natural ambient particulate matter (pollen) will become more important.

1.3 Impact of heatwaves on lung health

Europe and the eastern Mediterranean are the regions of the world most vulnerable to the health impacts of heat because of their ageing populations, high prevalence of chronic disease, and rising levels of urbanisation.[78]

"That alone should put European decision makers on red alert," said Vijoleta Gordeljevic, health and climate change coordinator at the Health and Environment Alliance (HEAL), a European not-for-profit body addressing how the natural and built environments affect health in the EU.

Higher temperatures particularly impact people with pre-existing conditions such as cardiovascular and respiratory diseases.[79] Death rates of people with chronic lung conditions such as COPD and asthma rise during heatwaves,[80] and estimates suggest that for each Celsius degree increase in temperature, premature death risk among respiratory patients is six times that of the general population.[81]

Deaths attributable to heatwaves are expected to rise significantly in Europe this century.[82] In the heatwave of summer 2003, there were more than 70,000 excess deaths in 12 European countries, and similar high summer temperatures are expected to be the norm by the middle of the century in Europe.[83,84]

One analysis predicted that there will be more than twice as many heat-related respiratory hospital admissions between 2021 and 2050 as there were between 1981 and 2010 in

[78] Watts N, Amann M, Arnell N et al. The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises. Lancet. 2021 Jan 9;397(10269):129-70.
[79] WHO. Heat and health. 2018. Available from: https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health
[80] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[81] D'Amato G, Vitale C, De Martino A et al. Effects on asthma and respiratory allergy of Climate change and air pollution. Multidiscip Respir Med 2015; 10, 39 https://doi.org/10.1186/s40248-015-0036-x
[82] Kendrovski V, Baccini M, Martinez G et al. Quantifying projected heat mortality impacts under 21st-century warming conditions for selected European countries. Int. J. Environ. Res. Public Health. 2017;14:729. Astrom C. et al. Vulnerability reduction needed to maintain current burdens of heat-related mortality in a changing climate-magnitude and determinants. Int. J. Environ. Res. Public Health. 2017;14:741.
[83] Robine JM, Cheung SL, Le Roy S et al. Report on excess mortality in Europe during summer 2003. EU Community Action Programme for Public Health, grant agreement 2005114. Montpellier: 2003 Heat Wave Project; 2007.
[84] D'Amato G, Pawankar R, Vitale C et al. Climate change and air pollution: effects on respiratory allergy. Allergy Asthma Immunol Res. 2016;8(5):391-5.

the EU-27.[85] The southern region of Europe is expected to be most affected, with heat-related respiratory illnesses expected to triple.[86]

People over age 65 and outdoor workers are particularly vulnerable to the adverse effects of heatwaves.[87] Mortality from heatwaves has increased by 53.7% in those aged 65 or more in the last 20 years.[88]

Young children and older adults appear to be particularly vulnerable to rapid fluctuations in ambient temperature.[89] For example, an increase in the incidence of childhood pneumonia in Australia has been associated with sharp temperature drops.[90]

1.4 Impact of aeroallergens (pollen) on lung health

Climate change is having a significant impact on the production and dispersal of pollen across Europe,[91,92] which can have a significant impact on respiratory health, particularly for people living with asthma and allergies.

Allergy to grass pollen is the most common pollen allergy in Europe,[93] but rising temperatures and CO_2 levels are expanding the geographic range of other allergenic plants, including ragweed, considered to produce one of the most potent aeroallergens (Figure 10).[94] These factors are also extending the season during which plants can grow and release pollen and increasing the concentration of pollen that is produced.[95]

There is also some evidence that some plants can produce pollens that are more allergenic when it is hotter, said Isabella Annesi-Maesano, research director at the French NIH (INSERM) and deputy director of the Desbrest Institute of Epidemiology and Public Health (IDESP), INSERM and University of Montpellier, France.[96,97] "When you have the same content of pollen in two different periods, the content of allergen in the pollen is higher in the case of higher temperature, so this means that people are at higher risk from the same number of pollen."

[85] Åström C, Orru H, Rocklöv J et al. Heat-related respiratory hospital admissions in Europe in a changing climate: a health impact assessment. BMJ Open. 2013;3:e001842.
[86] Ibid.
[87] Lancet. The Lancet Countdown: the 2020 report. Available from: https://www.lancetcountdown.org/2020-report/
[88] Ibid.
[89] Mirsaeidi M, Motahari H, Taghizadeh Khamesi M et al. Climate change and respiratory infections. Ann Am Thorac Soc. 2016;13(8):1223-30.
[90] Ibid.
[91] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[92] D'Amato G, Chong-Neto HJ, Monge Ortega OP et al. The effects of climate change on respiratory allergy and asthma induced by pollen and mold allergens. Allergy. 2020;75(9):2219-28.
[93] D'Amato G, Cecchi L, Bonini S et al. Allergenic pollen and pollen allergy in Europe. Allergy. 2007;62(9):976-90.
[94] Rasmussen K, Thyrring J, Muscarella R et al. Climate-change-induced range shifts of three allergenic ragweeds (Ambrosia L.) in Europe and their potential impact on human health. PeerJ. 2017;5:e3104.
[95] Barnes CS. Impact of climate change on pollen and respiratory disease. Curr Allergy Asthma Rep. 2018;18(11):59.
[96] El Kelish A, Zhao F, Heller W et al. Ragweed (Ambrosia artemisiifolia) pollen allergenicity: SuperSAGE transcriptomic analysis upon elevated CO_2 and drought stress. BMC Plant Biol. 2014;14:176.
[97] Ahlholm JU, Helander ML, Savolainen J. Genetic and environmental factors affecting the allergenicity of birch (Betula pubescens ssp. czerepanovii [Orl.] Hämet-Ahti) pollen. Clin Exp Allergy. 1998;28:1384-8.

Figure 10: Ragweed is predicted to rise. Monthly current (baseline) and future (2041-2060) ragweed pollen counts (grains per cubic meter) across Europe

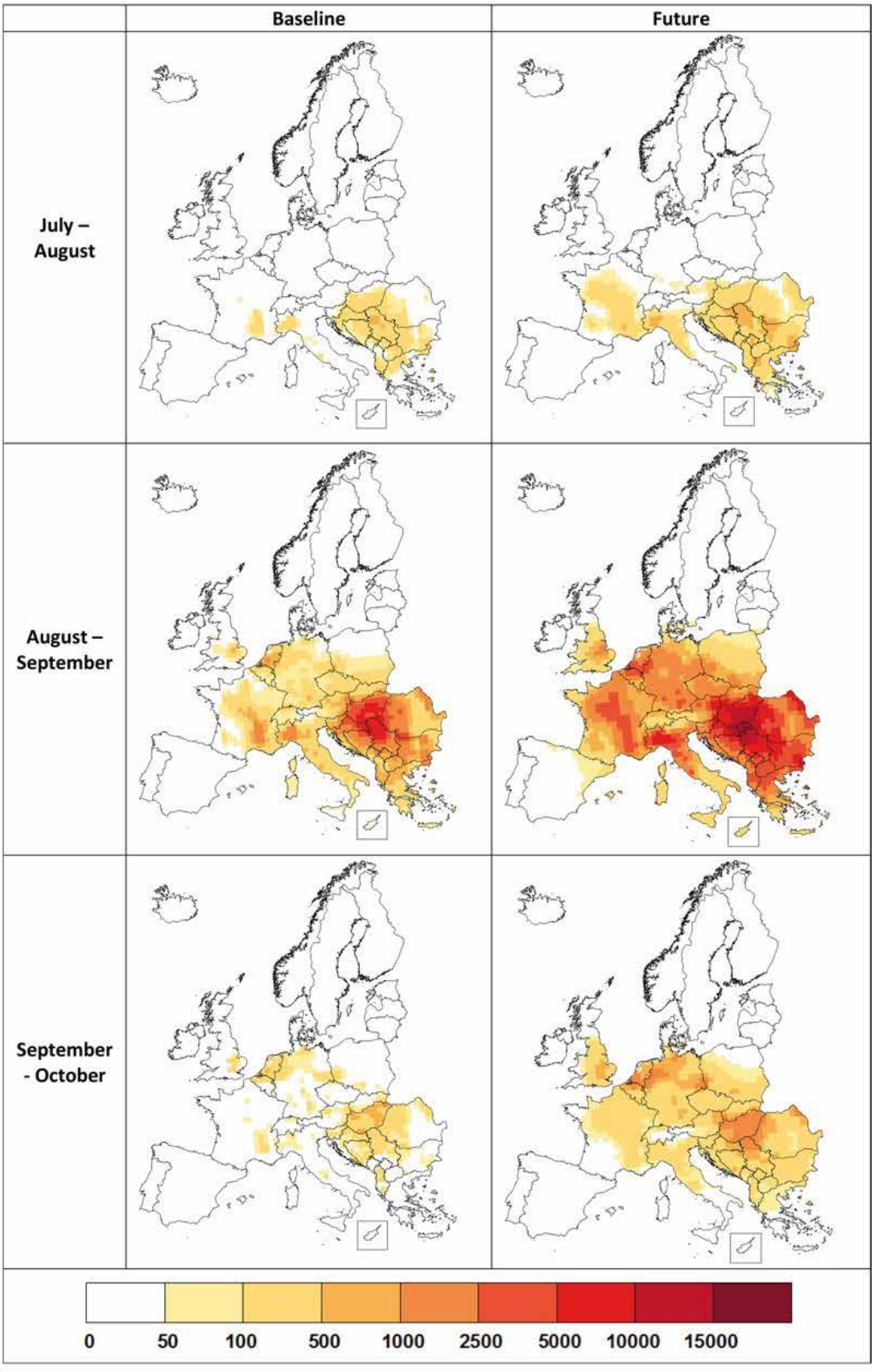


Image reproduced with permission from IR Lake.

Source: Lake IR, Jones NR, Agnew M, et al. Climate Change and Future Pollen Allergy in Europe [published correction appears in Environ Health Perspect. 2018 Jul 11;126(7):079002]. Environ Health Perspect. 2017;125(3):385-391.

People with pollen allergies experience hay fever (allergic rhinitis) during the pollen season, but high pollen concentrations can also have more serious implications for their respiratory health. People living with asthma exhibit reduced lung function and increased pulmonary inflammation after exposure to pollen, which can result in greater use of over-the-counter allergy medications and more interactions with health services, including emergency department visits.[98] Higher pollen concentrations and longer pollen seasons, as a result of climate change, are expected to increase the frequency and severity of such reactions.[99]

The prevalence of pollen allergies is growing in Europe, especially among children, of whom nearly 40% have pollen allergies,[100,101] but this is expected to increase dramatically because of climate change. Modelling suggests that sensitivity to ragweed alone will more than double, from 33m to 77m people, by 2041-2060 (Figure 10).[102] While the proportion of the population sensitised to ragweed pollen will increase in countries where there is already an existing ragweed problem, such as Hungary and the Balkans, the greatest increases are expected to occur in countries where sensitisation is uncommon, such as Germany, Poland and France.[103]

Parietaria judaica is another plant with the potential to spread to different regions of Europe because of climate change which produces pollen considered damaging aeroallergens. It is responsible for many cases of severe pollen asthma in the Mediterranean regions of southern Europe.[104,105,106]

Around 30% of the population of southern Italy is sensitive to *Parietaria judaica* and experiences symptoms between March and July, and its pollen is able to induce asthma because of its small size, said Professor Gennaro D'Amato, professor of respiratory medicine, School of Specialisation in Respiratory Diseases, University of Naples Federico II, director, Division of Respiratory Diseases and Allergy, High Specialty Hospital A. Cardarelli, Napoli, Italy and member G7 International Committee on Climate Change and Health.

"Grass pollen measures 20-25 microns and are able to induce nasal rhinitis, but usually cannot reach the peripheral airways," he explained. "However, pollen of *Parietaria judaica* is tiny—about 10 microns—so is able to reach the peripheral airways inducing asthma."

It is important for people with allergic rhinitis to be aware of the pollen calendar, which is available on the internet, he said. This allows them to prevent exacerbations by antihistamines and nasal corticosteroids, and they should do their best to avoid going outside when levels are particularly high and when their susceptibility to pollen is likely to be highest, such as during thunderstorms and when air pollution levels are high, Professor D'Amato said.

[98] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[99] Lake IR, Jones NR, Agnew M et al. Climate change and future pollen allergy in Europe [published correction appears in Environ Health Perspect. 2018;126(7):079002]. Environ Health Perspect. 2017;125(3):385-91.
[100] Clot B, Gilge S, Hajkova L et al. The EUMETNET AutoPollen programme: establishing a prototype automatic pollen monitoring network in Europe. Aerobiologia. 2020.
[101] D'Amato G, Cecchi L, Bonini S et al. Allergenic pollen and pollen allergy in Europe. Allergy. 2007;62(9):976-90.
[102] Lake IR, Jones NR, Agnew M et al. Climate change and future pollen allergy in Europe [published correction appears in Environ Health Perspect. 2018;126(7):079002]. Environ Health Perspect. 2017;125(3):385-91.
[103] D'Amato G, Cecchi L, Bonini S et al. Allergenic pollen and pollen allergy in Europe. Allergy. 2007;62(9):976-90.
[104] Ibid.
[105] D'Amato G, Ruffilli A, Sacerdoti G et al. Parietaria pollinosis: a review. Allergy. 1992;47:443-9.
[106] Ciprandi G, Puccinelli P, Incorvaia C et al. Parietaria allergy: an intriguing challenge for the allergist. Medicina (Kaunas, Lithuania). 2018;54(6).

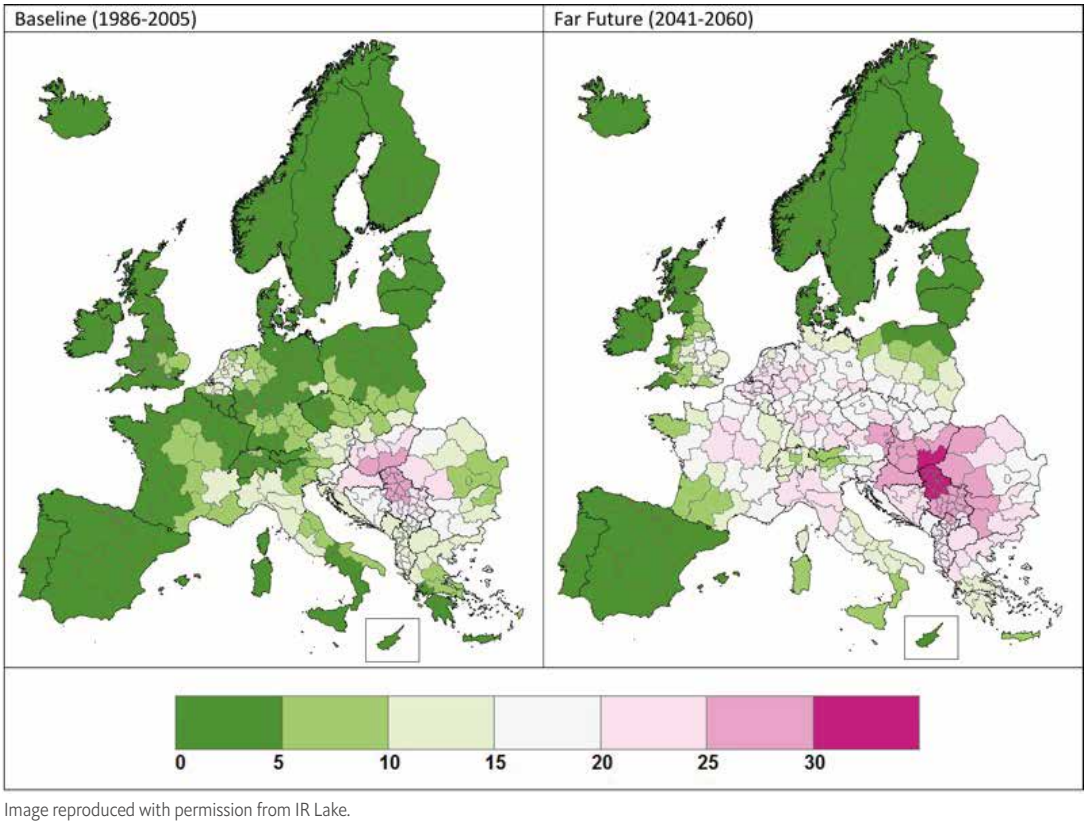
People who must go outdoors during these periods should consider wearing masks, he advises, and this is supported by research conducted during the pandemic.[107] "The masks we are wearing to protect against covid-19 are also protective against pollen."

Professor D'Amato and others have observed that patients with pollen allergy who frequently use masks experience a reduction in their symptoms.[108] He said: "It is our recommendation to use masks during the pollen season, particularly when there are thunderstorms."

Storms and pollution can worsen the impact of pollen, by promoting the release of allergen microparticles within the pollen, he explained.

Figure 11: Predicted rise in sensitisation to ragweed pollen at baseline (1986-2005) and in the far future (2041-2060)

(% of population)



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Source: Lake IR, Jones NR, Agnew M, et al. Climate Change and Future Pollen Allergy in Europe [published correction appears in Environ Health Perspect. 2018 Jul 11;126(7):079002]. Environ Health Perspect. 2017;125(3):385-391.

[107] Özener ZÇ, Öztürk BÖ, Aydın Ö et al. Coincidence of pollen season and coronavirus disease 2019 pandemic: less time outdoors—lesser allergy symptoms in 2020. Asia Pac Allergy. 2021;11(2):e16.
[108] Ibid.

1.5 Extreme weather events and impact on lung health

Rising temperatures also provoke other environmental events that impact respiratory health, such as wildfires, dust storms and thunderstorms.

1.5.1 Thunderstorms

Increased frequency and severity of storms due to climate change will increase adverse respiratory events.[109] In particular, it has been noted that there is an association between the onset of a thunderstorm, a rise in pollen concentration and the onset of asthma epidemics.[110]

High winds, heavy precipitation and thunderstorms can lead to sudden bursts of allergen release and can keep large numbers of pollen and spore particulates suspended at ground level.[111,112,113]

"Strong winds blow pollen from trees and smaller plants, meaning that people are exposed unexpectedly to a huge amount of these pollens concentrating in the area that is closer to the ground," explained Professor Annesi-Maesano.

The increased humidity of thunderstorms is particularly effective at trapping allergen particles at ground level.[114]

Professor D' Amato who with Professor Annesi-Maesano has published many research papers on the impact of thunderstorms and air pollution on pollen, explained that the rain or humidity that accompanies thunderstorms may induce hydration of pollen grains, which then burst and release an aerosol of allergenic microparticles.[115] These microparticles can trigger exacerbations of respiratory disease, particularly among individuals with allergies and asthma—a phenomenon known as thunderstorm asthma.[116]

"The pollen absorbs water and as a consequence is ruptured by osmotic shock and releases the components of its cytoplasm, which contains allergenic microparticles. There is an aerosol of allergens during these events," he said. "As a consequence, if someone has a pollen allergy that is limited to their nose, they suddenly experience asthma because the microparticle-carrying allergens that are released are able to reach peripheral airways, inducing asthma, sometimes causing near fatal asthma attacks."

The most severe examples of thunderstorm asthma have been recorded in Australia. For example, a 2016 thunderstorm in Melbourne prompted an epidemic thunderstorm-asthma event, with 3,365 excess respiratory-related emergency department cases and 476 excess asthma-related hospital admissions within 30 hours of the storm and 10 related deaths.[117,118]

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[109] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[110] Ibid.
[111] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[112] Lake IR, Jones NR, Agnew M et al. Climate change and future pollen allergy in Europe [published correction appears in Environ Health Perspect. 2018;126(7):079002]. Environ Health Perspect. 2017;125(3):385-91.
[113] WHO. Protecting health in Europe from climate change: 2017 update. Copenhagen: World Health Organization; 2017.
[114] Thien F, Beggs P, Csutoros D et al. The Melbourne epidemic thunderstorm asthma event 2016: an investigation of environmental triggers, effect on health services, and patient risk factors. Lancet Planet Health. 2018;2(6):e255-63.
[115] D'Amato G, Liccardi G, Frenguelli G. Thunderstorm-asthma and pollen allergy. Allergy. 2007;62:11-6.
[116] D'Amato G, Chong-Neto HJ, Monge Ortega OP et al. The effects of climate change on respiratory allergy and asthma induced by pollen and mold allergens. Allergy. 2020;75(9):2219-28.
[117] Thien F, Beggs PJ, Csutoros D et al. The Melbourne epidemic thunderstorm asthma event 2016: an investigation of environmental triggers, effect on health services, and patient risk factors. Lancet Planet Health. 2018;2(6):E255-63.
[118] Thien F. Melbourne epidemic thunderstorm asthma event 2016: lessons learnt from the perfect storm. Respirology. 2018;23:976-7.

Smaller events have also been studied and reported in Italy and the UK.[119,120]

1.5.2 Wildfires

When the temperature increases, then the risk of forest fires increases as well, and that impacts upon air pollution through the release of particulate matter, experts said. "We know through time series studies that if you get increases in particulate matter, then you're going to see more people with respiratory disease taking more medication, more people going to see the doctors and more people even being admitted to hospital because of an exacerbation," said Professor Kelly.

Higher temperatures, droughts and lower soil moisture related to climate change are all risk factors for wildfires, and the season for wildfires is growing longer as warmer temperatures are allowing fires to start earlier and extend into later months.[121]

Emissions from wildfires can travel up to 1,000 km, thus posing a threat to respiratory health over a wide area.[122] Emissions include particulate matter; carbon monoxide; nitrogen oxides, including NO_2 and nitric oxide; and volatile organic compounds. These emissions increase the risk of asthma and COPD exacerbations, impair lung function, and increase the risk of respiratory infections. The impact of these emissions is visible through increased hospitalisations, emergency department visits and use of asthma medications.[123,124,125]

People living with respiratory diseases are most likely to be affected by wildfires, but symptoms of decreased lung function have also been reported by healthy individuals after wildfires.[126] One study examining the impacts of wildfire smoke ten years after the 1997 Indonesian forest fires found that people exposed to emissions from the fire had poorer lung capacity, poorer self-reported general health, and poorer physical functioning than those who had not been exposed.[127]

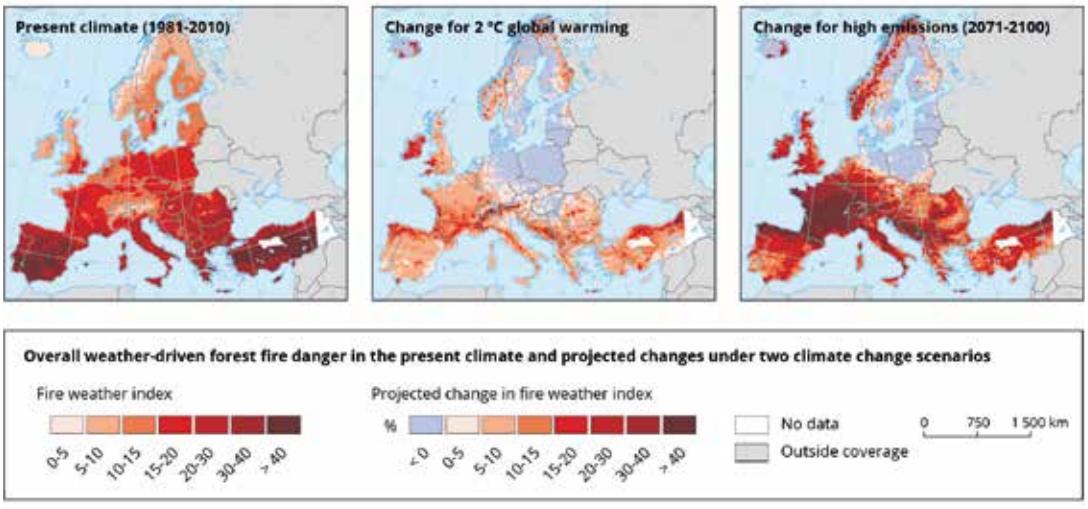
Those most vulnerable to adverse effects of wildfire smoke include people over age 65, those with pre-existing cardiac or respiratory conditions, people from lower socioeconomic areas and children because of their less mature respiratory system, higher breathing rate relative to body size and greater time spent outdoors.[128]

[119] D'Amato M, Annesi-Maesano I, Molino A et al. Temporali e attacchi d'asma durante le stagioni polliniche [Thunderstorm and asthma outbreaks during pollen season]. Epidemiol Prev. 2017;41(3-4):208-11.
[120] D'Amato G, Liccardi G, Frenguelli G. Thunderstorm-asthma and pollen allergy. Allergy. 2007;62(1):11-6.
[121] Xu R, Yu P, Abramson MJ et al. Wildfires, global climate change, and human health. N Engl J Med. 2020;383(22):2173-81.
[122] Ibid.
[123] Liu JC, Pereira G, Uhl SA et al. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. Environ Res. 2015;136:120-32.
[124] Reid CE, Brauer M, Johnston FH et al. Critical review of health impacts of wildfire smoke exposure. Environ Health Perspect. 2016;124(9):1334-43.
[125] Xu R, Yu P, Abramson MJ et al. Wildfires, global climate change, and human health. N Engl J Med. 2020;383(22):2173-81.
[126] De Sario M, Katsouyanni K, Michelozzi P. Climate change, extreme weather events, air pollution and respiratory health in Europe. Eur Respir J. 2013;42(3):826-43.
[127] Xu R, Yu P, Abramson MJ et al. Wildfires, global climate change, and human health. N Engl J Med. 2020;383(22):2173-81.
[128] Ibid.

Over a third of the total land area of Europe is covered by forests, and climate change projections predict increasing risk of wildfires, particularly in southern Europe (Figure 12). There will also be an increase in the length and severity of the fire season.[129,130,131]

Large forest fires have already become more commonplace in recent years in Europe, particularly in countries in the Mediterranean region.[132] In 2018, more European countries suffered from large forest fires than ever before, including in central and northern Europe. Sweden experienced its worst fire seasons ever and required international fire-fighting assistance through the European Civil Protection Mechanism.[133]

Figure 12: Overall weather-driven forest fire danger in the present climate and projected changes under two climate change scenarios



Source: European Environment Agency, Indicator assessment- Forest fires, 2020.

[129] European Environment Agency. Indicator assessment: forest fires. 2020. Available from: https://www.eea.europa.eu/data-and-maps/indicators/forest-fire-danger-3/assessment
[130] De Rigo D, Liberta G, Durrant T et al. Forest fire danger extremes in Europe under climate change: variability and uncertainty. Luxembourg: Publications Office of the European Union; 2017. Available from: https://publications.jrc.ec.europa.eu/repository/handle/JRC108974
[131] Borunda, A. Are Europe's historic fires caused by climate change? National Geographic, 31 Jul 2018.
[132] European Environment Agency. Indicator assessment: forest fires. 2020. Available from: https://www.eea.europa.eu/data-and-maps/indicators/forest-fire-danger-3/assessment
[133] Ibid.

1.5.3 Desert dust

Desert dust is another form of particulate matter likely to increase as a result of climate change, and it can travel much farther than particulates from forest fires.

Global warming increases desertification, so it is likely to increase the volume of atmospheric dust.[134] As well as particulates, dust storms can carry fungal spores (which contain allergens responsible for asthma and allergies), viruses and pollen vast distances.[135]

In recent years, Europe has experienced an increase in the severity and frequency of dust storms that involve particulate matter travelling from North Africa. While southern Europe has been most affected, countries farther north, such as the UK, also suffer the impact of Saharan dust.[136]

Previously there was a perception that desert dust did not have an adverse effect on respiratory health because it was "natural," said Professor Annesi-Maesano, but the evidence now suggests otherwise.

Modelling studies have linked days with high levels of desert dust in southern Europe to increased respiratory admissions and mortality,[137] and some studies have found higher rates of asthma, tracheitis, pneumonia, allergic rhinitis and silicosis linked to cases of desert storms.[138]

"Breathing in desert dust can exacerbate asthma or COPD," said Professor Kelly, "as can particles from our own soil, generated when the ground gets heated and aerated, and the smaller particles move up into the air."

The increased risk brought about by climate change of inhaling soil increases the risk of fungal infections. Increased respiratory fungal infections have been reported after storms, earthquakes and other natural or human activity affecting the soil.[139] For example, an outbreak of coccidioidomycosis, which is characterised by fever, chest pain and coughing and is transmitted by inhalation of airborne spores, occurred in California in 1977. There were 130 cases within two to four weeks after a severe natural dust storm.[140]

1.5.4 Floods

Heavy rainfall and more frequent storms brought about by climate change will cause rising sea levels, increased flooding and more damp buildings, conditions that promote the growth of and exposure to mould spores.[141,142,143]

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[134] Gunnarsson TG, Arnalds Ó, Appleton G et al. Ecosystem recharge by volcanic dust drives broad-scale variation in bird abundance. Ecol Evol. 2015;5(12):2386-96.
[135] D'Amato G, Holgate ST, Pawankar R et al. Meteorological conditions, climate change, new emerging factors, and asthma and related allergic disorders. A statement of the World Allergy Organization. World Allergy Organ J. 2015;8(1):25.
[136] Met Office. What is Saharan dust? https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/wind/saharan-dust
[137] Stafoggia M, Zauli-Sajani S, Pey J et al. Desert dust outbreaks in southern Europe: contribution to daily PM_{10} concentrations and short-term associations with mortality and hospital admissions. Environ Health Perspect. 2016;124(4):413-9.
[138] Linares C, Díaz J, Negev M et al. Impacts of climate change on the public health of the Mediterranean Basin population: current situation, projections, preparedness and adaptation. Environ Res. 2020;182:109107.
[139] Mirsaeidi M, Motahari H, Taghizadeh Khamesi M et al. Climate change and respiratory infections. Ann Am Thorac Soc. 2016;13(8):1223-30.
[140] Ibid.
[141] D'Amato G, Chong-Neto HJ, Monge Ortega OP et al. The effects of climate change on respiratory allergy and asthma induced by pollen and mold allergens. Allergy. 2020;75(9):2219-28.
[142] Demain JG. Climate change and the impact on respiratory and allergic disease: 2018. Curr Allergy Asthma Rep. 2018;18(4):22.
[143] European Environment Agency. Indicator assessment: floods and health. 2021. Available from: https://www.eea.europa.eu/data-and-maps/indicators/floods-and-health-1/assessment

The link between moulds and asthma and rhinitis is well documented.[144] Mould allergens are responsible for severe allergic asthma and rhinitis. In addition, mould metabolites, such as microbial volatile organic compounds, can cause non-allergic asthma and chronic bronchitis, while exposure to certain types of mould can cause respiratory infections.[145,146]

Flooding soil that is normally dry and housing materials results in fungal growth leading to fungal and polymicrobial respiratory infections, which in the worst cases can be life threatening.[147] Respiratory infections were responsible for 13% of all deaths after a Bangladesh flood in 1988, with acute respiratory tract infections responsible for nearly half of these.[148]

Damp buildings and mould are associated with a 30-80% increase in adverse health events and a 30-50% increase in respiratory and asthma-related events.[149] These include increased coughing or wheezing, pneumonia, asthma attacks and upper respiratory tract infections.[150,151]

Children are particularly susceptible to the health effects of damp, which include respiratory disorders such as irritation of the respiratory tract, allergies and exacerbation of asthma.[152]

Additionally, though less frequently discussed, experiences with natural disasters such as floods can intensify the burden of depression, anxiety and stress, which are risk factors for asthma.[153]

In terms of the overall repercussions of climate change globally, said Professor Kelly, "flooding is probably the biggest climate change issue, and where you get flooding, you have the potential of increases in infectious disease."

Northwestern Europe is considered at particular risk of increased flooding as a result of climate change (Figure 13).[154] Climate change projections in a high emissions scenario suggest there will be a 35% increase in heavy rainfall in most parts of Europe in autumn and winter by the end of the 21st century.[155]

The number of people predicted to be affected by coastal flooding per year in the EU by the end of the 21st century ranges from 775,000 to 5.5m, depending on the emissions scenario.[156] In a scenario of medium-level emissions of greenhouse gases, it is estimated that river flooding will affect 300,000 people per year in the EU by the 2050s, and by the 2080s this will have reached 390,000 people—more than double the number affected in the 1961-1990 period.[157]

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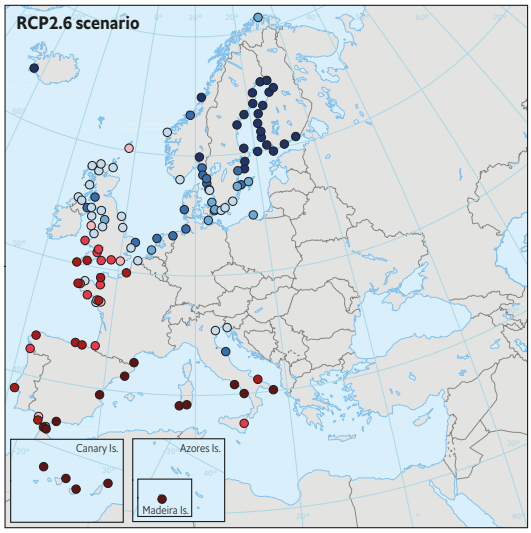
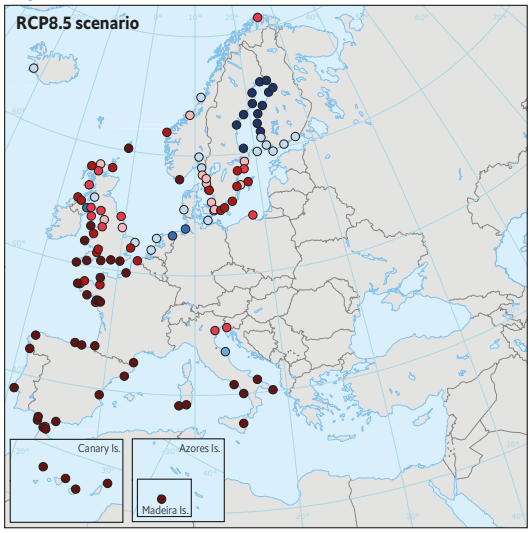
[144] Mendell MJ, Mirer AG, Cheung K et al. Respiratory and allergic health effects of dampness, mold, and dampness-related agents: a review of the epidemiologic evidence. Environ Health Perspect. 2011;119:748-56.
[145] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[146] Flamant-Hulin M, Annesi-Maesano I, Caillaud D. Relationships between molds and asthma suggesting non-allergic mechanisms. A rural-urban comparison. Pediatr Allergy Immunol. 2013;24:345-51.
[147] Mirsaeidi M, Motahari H, Taghizadeh Khamesi M et al. Climate change and respiratory infections. Ann Am Thorac Soc. 2016;13(8):1223-30.
[148] Ibid.
[149] Health impacts of climate change: Mold, respiratory illness, and how you can protect yourself. San Francisco Health Profile, 2015. Available from: https://insight.livestories.com/s/health-impacts-of-climate-change-mold-and-respiratory-illness/567b2bb962b12600174b9e02/
[150] Ibid.
[151] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[152] WHO. Chronic respiratory diseases: data and statistics. https://www.euro.who.int/en/health-topics/noncommunicable-diseases/chronic-respiratory-diseases/data-and-statistics
[153] D'Amato G, Cecchi L, D'Amato M et al. Climate change and respiratory disease. Eur Respir Rev. 2014;23(132):161-9.
[154] Blöschl G, Hall J, Viglione A et al. Changing climate both increases and decreases European river floods. Nature. 2019;573:108-11.
[155] European Environment Agency. Why does Europe need to limit climate change and adapt to its impact? Available from: https://www.eea.europa.eu/highlights/why-does-europe-need-to
[156] European Environment Agency. Indicator assessment: floods and health. 2021. Available from: https://www.eea.europa.eu/data-and-maps/indicators/floods-and-health-1/assessment
[157] Ibid.

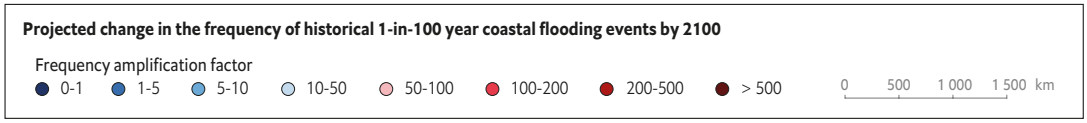
Figure 13: Projected change in the frequency of one-in-100 year coastal flooding events between 2010 and 2100 under different emissions scenarios

Low emissions scenario



High emissions scenario





Source: Change in the frequency of flooding events in Europe given projected sea level rise under two climate scenarios — European Environment Agency (europa.eu).

1.6 The relationship between pollution and climate change

Climate change and air quality are extremely closely linked and often interdependent.

"They're two sides of the same coin really," said Ms Gordeljevic. "Bluntly speaking, air quality is strongly dependent on weather and it's therefore sensitive to climate change.

"There's an interplay between climate change and air pollution which is difficult to disentangle and which means the two must be tackled together: you need to address one to address the other, and by addressing one you will address the other."

Much of the responsibility for global warming lies in the release of greenhouse gases, particularly CO_2, from the burning of fossil fuels, which also causes air pollution.

"It's the extraction and burning of fossil fuels that is the main cause of CO_2 emissions, but it's also a major source of air pollutants," Ms Gordeljevic said. "Air pollutants contribute to climate change as well by affecting the amount of incoming sunlight that is reflected or absorbed by the atmosphere, so some pollutants have a warming effect and others have a cooling effect on the Earth."

Methane, black carbon and ozone have a warming effect, she said. "They are among the top contributors to global warming after CO_2."

In 2018, the UN formally recognised both outdoor and indoor pollution as a risk factor for non-communicable diseases, alongside factors such as smoking, poor diet, lack of exercise and alcohol.[158]

In a report published in 2015, the WHO estimated that the economic cost of ambient and household pollution to the WHO European region was US$1.6tn in 2010, based on 663,000 premature deaths and approximately 13m disability-adjusted life years.[159] This amount is equivalent to nearly one-tenth of the gross domestic product (GDP) of the entire EU in 2013.[160] In eight of the 48 countries in the WHO European region, all in the eastern part of the region, the economic cost of premature deaths from air pollution alone was more than 20% of the country's GDP.[161]

Approximately 482,000 of the premature deaths in 2012 in the WHO European region were from heart and respiratory diseases, blood vessel conditions and strokes and lung cancer due to ambient air pollution.[162] A further 117,200 premature deaths in the WHO European region were due to indoor air pollution, and the number of these deaths was five times greater in low- and middle-income countries than in high-income countries in this region, which includes countries such as Armenia, Moldova, Tajikistan and Ukraine.[163]

A study by the Organisation for Economic Co-operation and Development (OECD) of the impact of air pollution on economic activity in Europe published in 2019 estimated that a 1μg/m^3 increase in annual mean $PM_{2.5}$ concentration alone would decrease Europe's GDP by 0.8%,[164] and 95% of this impact is due to reductions in output per worker.[165]

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[158] UN. Political declaration of the third high-level meeting of the General Assembly on the prevention and control of non-communicable diseases. Time to deliver: accelerating our response to address noncommunicable diseases for the health and well-being of present and future generations. New York: United Nations; 2018. Available from: https://ncdalliance.org/sites/default/files/Political_Declaration_final_text_0.pdf

[159] WHO. Economic cost of the health impact of air pollution in Europe: clean air, health and wealth. 2015. https://www.euro.who.int/__data/assets/pdf_file/0004/276772/Economic-cost-health-impact-air-pollution-en.pdf

[160] WHO. Air pollution costs European economies US$1.6 trillion a year in diseases and deaths, new WHO study says. 2015. https://www.euro.who.int/en/media-centre/sections/press-releases/2015/04/air-pollution-costs-european-economies-us$-1.6-trillion-a-year-in-diseases-and-deaths,-new-who-study-says

[161] WHO. Economic cost of deaths from air pollution (outdoor and indoor) per country, as a percentage of GDP WHO European Region, 2015. https://www.euro.who.int/__data/assets/pdf_file/0008/276956/PR_Economics-Annex_en.pdf

[162] WHO. Improving environment and health in Europe: how far have we gotten? Copenhagen: WHO Regional Office for Europe; 2015. Available from: https://www.euro.who.int/__data/assets/pdf_file/0018/276102/Improving-environment-health-europe-en.pdf

[163] Ibid.

[164] OECD. The economic cost of air pollution: evidence from Europe. Paris: Organisation for Economic Co-operation and Development; 2019. Available from: https://www.oecd-ilibrary.org/economics/the-economic-cost-of-air-pollution-evidence-from-europe_56119490-en?_ga=2.126324100.868082654.1623956458-911141665.1623849576

[165] Ibid.

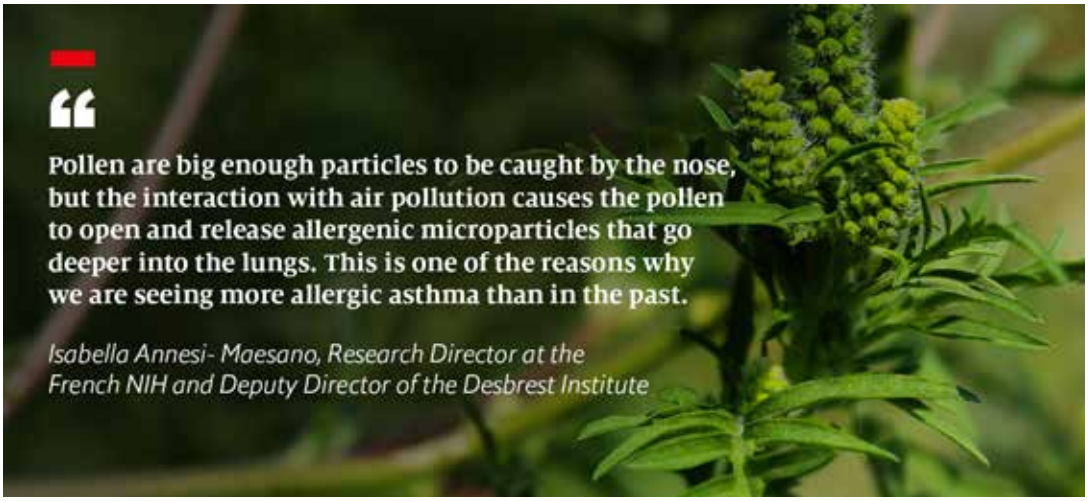
The OECD concluded that more stringent air quality regulations could be warranted based solely on economic grounds, as the direct economic benefits from air pollution control policies are much larger than the abatement costs, even when ignoring the large benefits in terms of avoided mortality.[166]

Long-term exposure to fine particulate matter ($PM_{2.5}$) was responsible for 417,000 premature deaths in Europe (including 41 countries) in 2018, of which around 379,000 were in the EU-28.[167] In addition, NO_2 was responsible for an additional 55,000 premature deaths in Europe (around 54,000 in the EU-28), and ozone was responsible for 20,600 (19,400 in the EU-28) (Table 1).[168]

Between 2009 and 2018, premature deaths from $PM_{2.5}$ fell by 13% in both Europe overall and in the EU-28, and those from NO_2 were reduced by more than half.[169] In contrast, premature deaths from ozone increased by 20% across Europe and by 24% for the EU-28.[170]

Air pollutants impact respiratory health directly, exacerbating existing respiratory conditions and affecting the lung development of children; air pollutants also worsen the effects of pollen.[171,172]

"When levels of pollutants, such as particulate matter, ozone or nitrogen dioxide are high, these gases and dust particles are able to induce inflammation of airways," Professor D'Amato explained. "When someone with pollen allergy inhales pollen grains and there is a background of inflammation, the effect of pollen allergy is sometimes catastrophic."



[166] OECD. The economic cost of air pollution: evidence from Europe. Paris: Organisation for Economic Co-operation and Development; 2019. Available from: https://www.oecd-ilibrary.org/economics/the-economic-cost-of-air-pollution-evidence-from-europe_56119490-en?_ga=2.126324100.868082654.1623956458-911141665.1623849576
[167] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report (EU-28 includes the UK)
[168] Ibid.
[169] Ibid.
[170] Ibid.
[171] D'Amato G, Pawankar R, Vitale C et al. Climate change and air pollution: effects on respiratory allergy. Allergy Asthma Immunol Res. 2016;8(5):391-5.
[172] WHO. Noncommunicable diseases and air pollution. 2019. https://www.euro.who.int/__data/assets/pdf_file/0005/397787/Air-Pollution-and-NCDs.pdf

Table 1: Premature deaths attributable to $PM_{2.5}$, NO_2 and O_3 exposure in 41 European countries and the EU-28, 2018

Country	Population (1 000)	$PM_{2.5}$		NO_2		O_3	
		Annual mean (a)	Premature deaths (b)	Annual mean (a)	Premature deaths (b)	SOMO35 (a)	Premature deaths (b)
Austria	8 822	13.6	6 100	17.7	790	6 731	420
Belgium	11 399	12.7	7 400	20.4	1 200	4 298	350
Bulgaria	7 050	21	12 500	19.0	1 100	3 765	320
Croatia	4 105	18	5 100	13.8	90	6 342	250
Cyprus	1 216	14.5	620	23.5	210	6 844	40
Czechia	10 610	18.3	10 900	15.5	300	6 946	580
Denmark	5 781	10.5	3 100	9.8	10	3 866	150
Estonia	1 319	7	610	7.1	< 1	2 793	30
Finland	5 513	5.9	1 700	8.6	< 1	2 351	90
France	64 456	10.6	33 100	15.9	5 900	5 274	2 300
Germany	82 792	12.3	63 100	19.1	9 200	5 674	4 000
Greece	10 741	18.3	11 800	21.0	3 000	7 157	650
Hungary	9 778	18.3	13 100	17.0	850	5 892	590
Ireland	4 830	7.8	1 300	11.0	50	2 556	60
Italy	60 484	15.5	52 300	20.1	10 400	6 490	3 000
Latvia	1 934	12.1	1 800	11.9	70	2 732	60
Lithuania	2 809	12.8	2 700	12.3	10	3 096	90
Luxembourg	602	10	210	20.2	40	4 604	10
Malta	476	12.5	230	10.4	< 1	5 498	10
Netherlands	17 181	12	9 900	20.4	1 600	3 620	410
Poland	37 977	21.7	46 300	15.6	1 900	5 095	1 500
Portugal	9 794	8.4	4 900	15.4	750	4 672	370
Romania	19 531	17.6	25 000	19.3	3 500	3 683	730
Slovakia	5 443	18.2	4 900	14.8	40	6 129	230
Slovenia	2 067	15.8	1 700	14.5	50	6 494	100
Spain	44 452	10.2	23 000	19.4	6 800	5 841	1 800
Sweden	10 120	6.1	3 100	8.7	< 1	3 465	240
United Kingdom	66 274	10	32 900	18.9	6 000	2 307	1 000
Albania	2 870	21.6	5 000	14.7	100	5 601	180
Andorra	75	8.5	30	18.1	< 1	6 593	< 1
Bosnia and Herzegovina	3 503	26.4	5 100	13.9	90	5 218	150
Iceland	348	4.7	60	10.4	< 1	1 999	< 1
Kosovo	1 799	28.2	4 000	17.0	90	3 922	80
Liechtenstein	38	8.6	20	16.5	< 1	7 045	< 1
Monaco	38	12.6	20	25.0	10	7 686	< 1
Montenegro	622	20.5	640	15.0	10	5 630	30
North Macedonia	2 075	30.7	3 000	19.0	130	3 533	50
Norway	5 296	6.4	1 400	10.0	40	3 128	90
San Marino	34	13.3	30	14.4	< 1	6 700	< 1
Serbia	7 001	26.3	14 600	17.3	430	3 500	280
Switzerland	8 484	9.8	3 500	17.6	270	7 214	350
EU-28 total	507 558	13.2	379 000	17.8	54 000	4 970	19 400
All countries total	539 742	13.5	417 000	17.6	55 000	4 962	20 600

Notes: (a) The annual mean (in µg/m³) and the SOMO35 (in µg/m³·days), expressed as population-weighted concentration, is obtained according to the methodology described by ETC/ATNI (2020d) and references therein and not only from monitoring stations.
(b) Total and EU-28 premature deaths are rounded to the nearest thousand (except for O_3, nearest hundred). The national totals are rounded to the nearest hundred or ten.
Source: European Environment Agency

"Generally, pollen are big enough particles to be caught by the nose, but the interaction with air pollution causes the pollen to open and release allergenic microparticles that go deeper into the lungs," Professor Annesi-Maesano explained. "This is one of the reasons why we are seeing more allergic asthma than in the past."

1.6.1 How outdoor air pollution impacts lung health

Short-term exposure to elevated levels of air pollution can exacerbate asthma, affect lung function, and increase respiratory and cardiovascular hospital admissions and deaths.[173] Exposure to air pollution over a longer term reduces life expectancy, mainly due to cardiovascular and respiratory causes and lung cancer.[174]

Burning fossil fuels produces numerous emissions that impact lung health, but this report looks in detail only at the effects of the key emissions. Others, including sulphur dioxide, carbon monoxide and dioxins, are not covered in detail.[175]

The advisory board emphasised that moving away from fossil fuels was a priority in order to tackle both climate change and air pollution, but there was disagreement over which emission deserved the most attention. Some advisory board members believe that $PM_{2.5}$ is more important than NO_2 or ozone, whereas others are less inclined to dismiss ozone and want to see action against methane because it is a major precursor to ozone and there are cost-effective solutions to tackle it.

Ground-level ozone

"Concentrations of every air pollutant in Europe have declined since the year 2000, with the exception of ozone," said Gerardo Sanchez Martinez, expert in environment, health and wellbeing at the European Environment Agency.[176] This is a major concern because ozone is a key contributor to morbidity and mortality from respiratory disease.

Professor D'Amato said: "Ozone is able to induce rhinitis, ocular rhinitis and asthma particularly on sunny days because it is produced by the action of the sun on nitrogen dioxide."

What is ozone?

Ozone is a gas composed of three atoms of oxygen (O_3). In terms of health, it can be good or bad, depending on where it is found.[177]

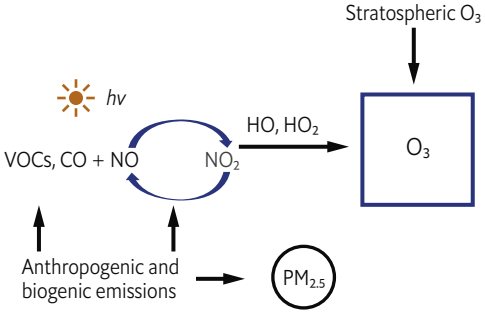
Stratospheric ozone, which is 'good' ozone, occurs naturally in the upper atmosphere, where it forms a protective layer that shields us from the sun's harmful ultraviolet rays.[178] This beneficial ozone has been partially destroyed by manmade chemicals, causing what is sometimes called a "hole in the ozone", raising the risk of skin cancer.

Ozone at ground level, known as tropospheric ozone, is a harmful air pollutant, and it is the main ingredient in "smog".[179]

[173] Public Health England. Review of interventions to improve outdoor air quality and public health. London: Public Health England; 2020.
[174] Ibid.
[175] Manisalidis I, Stavropoulou E, Stavropoulos A et al. Environmental and health impacts of air pollution: a review. Front Public Health. 2020;8:14.
[176] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[177] US Environmental Protection Agency. Ground-level ozone basics. 2021. https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics#:~:text=ozone%20can%20be%20%e2%80%9cgood%e2%80%9d%20or%20%e2%80%9cbad%e2%80%9d%20for%20health,living%20things%20from%20ultraviolet%20radiation%20from%20the%20sun
[178] Ibid.
[179] Ibid.

Figure 14: Formation of ground level ozone

(Ozone in the stratosphere can move downward to the troposphere, contributing to the "background" level of ground-level ozone.)



Key:
hv, photon
VOCs, volatile organic compounds
CO, carbon monoxide
NO, nitric oxide
NO_2, nitrogen dioxide
HO, the hydroxyl radical; HO_2, the hydroperoxy radical
$PM_{2.5}$, particulate matter with a diameter of 2.5 µm or less

Source: Zhang JJ, Wei Y, Fang Z. Ozone Pollution: A Major Health Hazard Worldwide. *Front Immunol*. 2019;10:2518. Published 2019 Oct 31.

Ground-level ozone is formed through atmospheric reactions between nitrogen oxides and volatile organic compounds in the presence of sunlight, so it often increases during higher temperatures (Figure 14).[180] Methane can also be a precursor to ground-level ozone.[181]

Ground-level ozone is a widely distributed pollutant in the atmosphere over north-west Europe and is expected to increase as climate change exacerbates the atmospheric conditions favourable to its creation.[182,183]

Emissions from cars, power stations and industry provide the chemicals required to create ground-level ozone, so it is most likely to reach unhealthy levels on hot sunny days in urban environments.[184] However, it can still reach high levels during colder months, and it can also be transported long distances by wind, meaning rural areas can also experience high ozone levels.[185]

Short-term elevations in ground-level ozone have been associated with increases in all-cause mortality around the world, including in less-polluted cities in western Europe.[186] The deadly 2003 heatwave in Europe was associated with high levels of ozone, and this is believed to have contributed to the excess mortality.[187] It is estimated that in 2010, long-term outdoor exposure to ozone air pollution contributed to more than 1m premature respiratory deaths globally—or approximately one in five of all respiratory deaths.[188]

"From a respiratory point of view, ozone is very, very damaging," said Professor Kelly. "The analogy I always use is that we use this

[180] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[181] Climate and Clean Air Coalition. Methane. https://www.ccacoalition.org/en/slcps/methane
[182] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[183] Zhang JJ, Wei Y, Fang Z. Ozone pollution: a major health hazard worldwide. Front Immunol. 2019;10:2518.
[184] Ibid.
[185] Ibid.
[186] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[187] Ibid.
[188] Malley CS, Henze DK, Kuylenstierna JCI et al. Updated global estimates of respiratory mortality in adults ≥30 years of age attributable to long-term ozone exposure. Environ Health Perspect. 2017;125:8.

gas ozone to disinfect our swimming pools, so it kills everything there. If inhaled in just small concentrations, it irritates our lungs, and if you have a respiratory condition, then you're even more sensitive to it."

As a respiratory irritant, ground-level ozone can cause bronchial inflammation and hyper-responsiveness, aggravating pre-existing respiratory conditions in both children and adults.[189]

Research has demonstrated that modest, short-term increases in ground-level ozone can escalate the risk of acute care visits and hospitalisation for asthma and COPD.[190] In addition, ground-level ozone exposure has been associated with deterioration in asthma control in Europe, resulting in greater medication use and missed days of school and work.[191]

Long-term exposure to ground-level ozone is also likely to contribute to the development of asthma.[192] Children are at a higher risk for ozone-related respiratory problems because their lungs are still developing and exposure results in a higher dose of ozone per body mass.[193]

Around 32% of the European population lived in areas with ozone (SOMO35) values above 6,000 μg/m^3.days in 2018 (Figure 15).[194]

The EU target for ozone is that daily eight-hour mean ozone levels should not exceed 120 μg/m^3 on more than 25 days per year, averaged over three years.[195] In 2018, 20 member states and five other reporting countries registered concentrations above 120 μg/m^3 on more than 25 occasions, and only 4% of all European monitoring stations reported figures below the lower WHO Air Quality Guidelines level

[189] Rice MB, Thurston GD, Balmes JR et al. Climate change. A global threat to cardiopulmonary health. Am J Respir Crit Care Med. 2014;189(5):512-9.
[190] Ibid.
[191] Ibid.
[192] Zhang JJ, Wei Y, Fang Z. Ozone pollution: a major health hazard worldwide. Front Immunol. 2019;10:2518.
[193] Ibid.
[194] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[195] Ibid.

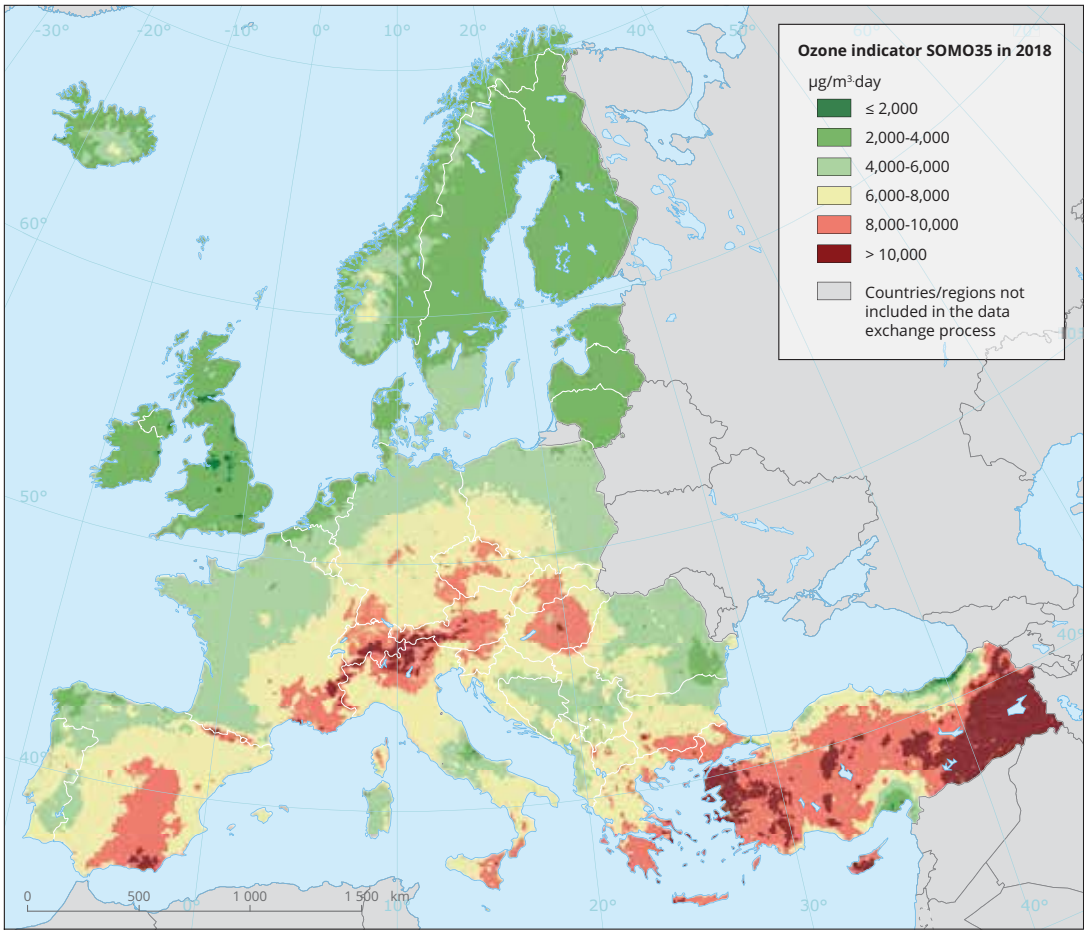
for the protection of human health (an eight-hour mean of 100 µg/m³).[196]

Professor Kelly said, "Ozone is already an issue in some southern European countries, like Greece and Italy, but in ten years' time, northern European countries could have similar ozone concentrations, and as a consequence, there's going to be a lot more related respiratory illnesses."

The largest increase in ozone-associated mortality and morbidity due to climate change (4-5%) in recent years (the period between 1961-1990 and 1990-2009) occurred in Belgium, Ireland, the Netherlands and the UK.[197] Over the next 40 years, it is anticipated that the largest increases in ozone-related mortality and morbidity will occur in Belgium, France, Spain and Portugal, while Nordic and Baltic countries will see a decrease.[198]

Figure 15: Ozone levels in Europe, 2018

Around 32% of the European population lived in areas with ozone (SOMO35) values above 6,000 µg/m³.days in 2018. SOMO35 is the yearly sum of maximum 8-hour ozone levels over 35 ppb (parts per billion, 70 µg/m³) (a measure of accumulated annual ozone concentrations used as an indicator of health hazards).



Reference data: ©ESRI

Source: European Environment Agency.https://www.eea.europa.eu/data-and-maps/figures/o3-indicator-somo35-in-2.

[196] Ibid.

[197] Orru H, Andersson C, Ebi KL et al. Impact of climate change on ozone-related mortality and morbidity in Europe. Eur Respir J. 2013;41(2):285.

[198] Ibid.

Nitrogen dioxide

Nitrogen dioxide, or NO_2, is a gaseous air pollutant produced by combustion of fossil fuels, particularly by older diesel vehicles.

Ground-level NO_2 can have harmful effects on lung health, including increased inflammation of the airways, worsened cough and wheezing, reduced lung function, increased asthma attacks and greater likelihood of emergency department visits and hospital admissions.[199] NO_2 may also be a cause of asthma in children.[200] However, NO_2's main contribution to respiratory ill health is that it is one of the ingredients in the chemical reaction that creates ground-level ozone.

While progress has been made to reduce NO_2 emissions, a significant proportion of Europe's population lives in areas where concentrations exceed air quality standards.[201] Road transport is the largest source of NOx (NO and NO_2) emissions in Europe, accounting for 39% in the EU-28 overall, with far greater levels found in urban areas.[202] An analysis of NOx levels in 30 European cities found that transport was responsible for 47% of NOx (Figure 16).[203]

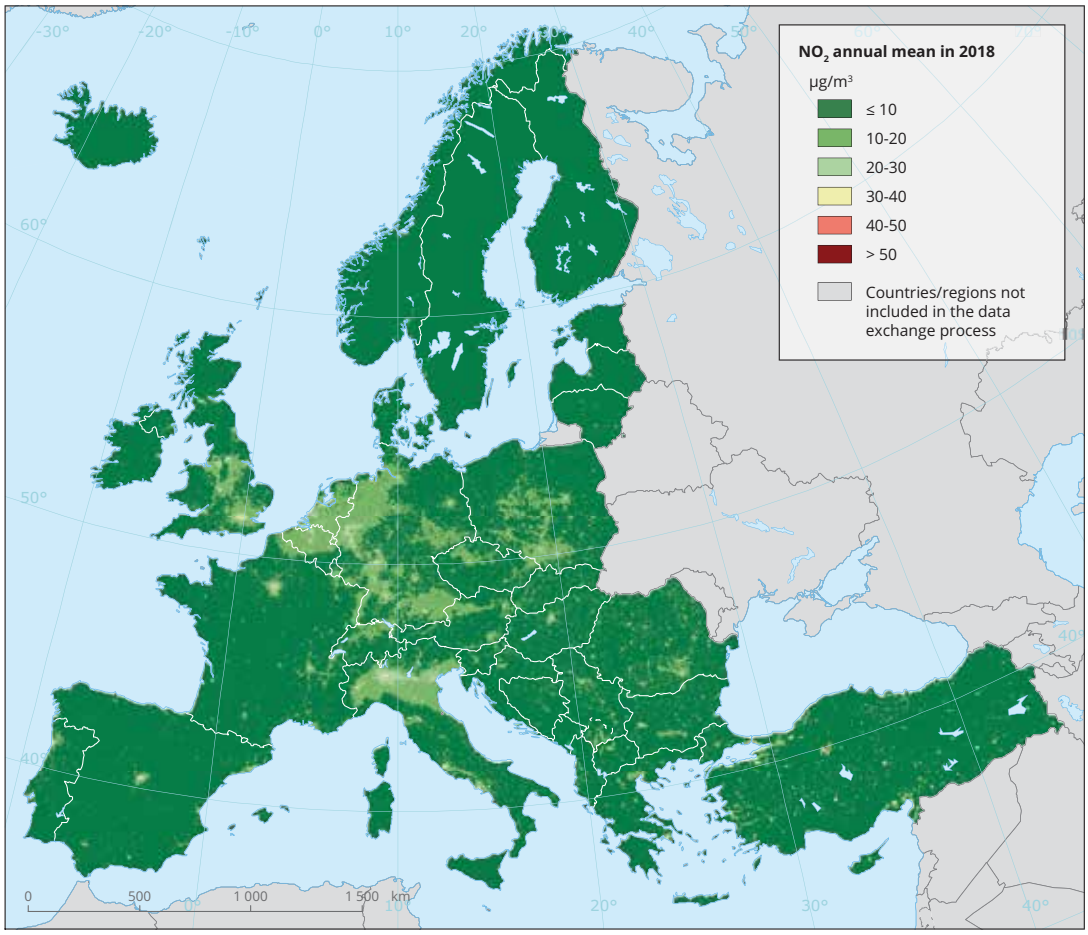
"Nitric oxide (the NO part of NOx) and ozone can't live together – they combine to produce NO_2," Professor Kelly said, "so in northern European cities, because there's so much NOx, ozone concentrations can be very low, but if you go outside the city, you could be experiencing higher ozone concentrations, because you haven't got the NOx there.

"As we clean up our city centres, and we don't have NOx emissions from diesel, in the future, ozone concentrations will increase in our cities."

[199] American Lung Association. Nitrogen dioxide. 2020. https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/nitrogen-dioxide
[200] Ibid.
[201] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[202] Degraeuwe B, Pisoni E, Peduzzi E et al. Urban NO_2 atlas. Luxembourg: Publications Office of the European Union; 2019. Available from: https://publications.jrc.ec.europa.eu/repository/handle/JRC118193
[203] Ibid.

Figure 16: NO_2 annual mean in 2018

In 2018, 16 EU member states and three other reporting countries recorded annual means of NO_2 above 40 µg/m³, which is the EU annual limit value and the level in the WHO Air Quality Guidelines for the protection of human health.



Reference data: ©ESRI

Source: European Environment Agency https://www.eea.europa.eu/data-and-maps/figures/no2-annual-mean-in-2.

Fine particulate matter

"Of all air pollutants, fine particulate matter is the cause of more premature death in Europe and around the world than any other by a significant margin," said Nathan Borgford-Parnell, scientific affairs co-ordinator, Climate and Clean Air Coalition.

A total of 417,000 premature deaths were attributed to fine particulate matter ($PM_{2.5}$) exposure across 41 European countries in 2018, compared with 55,000 attributed to NO_2 exposure and 20,600 to ozone exposure in 2018.[204]

Particulate matter is the term used to describe particles found in the air, which are classified by size. Smaller particulates pose the greatest risk to human health.[205] When inhaled, fine particulates ($PM_{2.5}$) are able to penetrate deep into the lungs and can sometimes get into the bloodstream.

The combustion of carbon-based fuels produces CO_2 and other pollutants such as particulate matter, which includes particles that can heat the Earth's atmosphere.[206] One such particulate is black carbon (BC), which is emitted from the domestic burning of solid fuels, particularly indoors, and high-emitting diesel engines. BC is likely to contribute to climate warming.[207]

In addition to its impact on climate change, particulate matter is a major contributor to local air pollution, and exposure to it can have a significant impact on respiratory health. Studies have shown that both short- and long-term exposure to air pollution including particulate matter can lead to reduced lung function, respiratory infection and aggravated asthma.[208]

According to the European Environment Agency (EEA), almost all city dwellers in Europe are exposed to air pollution levels that exceed WHO guidelines on particulate matter.[209] In 2018, about 76% of the population of the European area (excluding Turkey) was exposed to annual mean $PM_{2.5}$

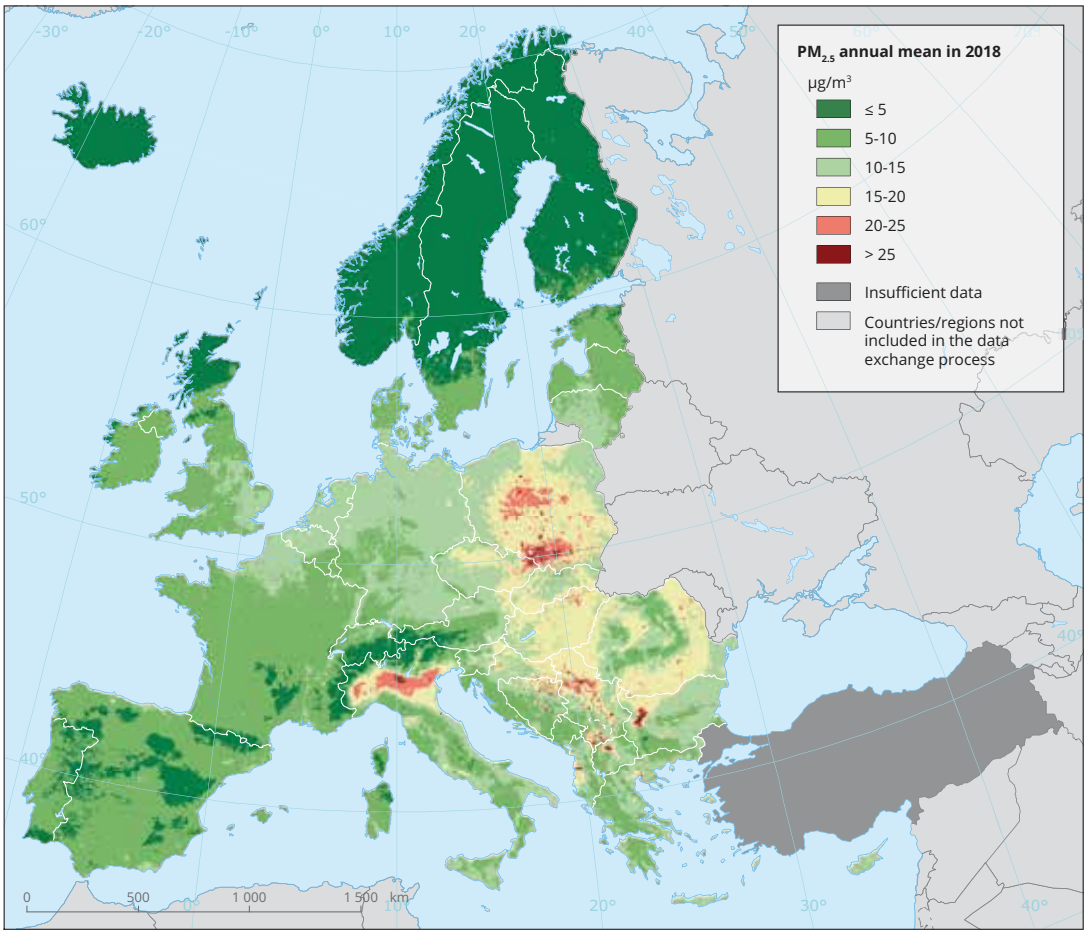
[204] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[205] US Environmental Protection Agency. Particulate matter (PM) pollution. 2021. https://www.epa.gov/pm-pollution
[206] Law K. Combined policies for better tackling of climate change and air pollution [Editorial]. Science for Environment Policy. 2010;24:1-3. Available from: https://ec.europa.eu/environment/integration/research/newsalert/pdf/24si_en.pdf
[207] Ibid.
[208] European Environment Agency. Air quality in Europe: 2020 report. Luxembourg: European Environment Agency; 2020. Available from: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report
[209] Ibid.

concentrations above the WHO Air Quality Guideline (10 µg/m^3), but only 5% were exposed if the lower EU limit value (25 µg/m^3) is used (Figure 17 and Table 1).[210]

Research also suggests that long-term exposure to fine particulate matter is associated with childhood respiratory disease.[211]

Figure 17: Particulate matter is a big killer in Europe. $PM_{2.5}$ annual mean in 2018

The EU limit value for $PM_{2.5}$ is an annual mean of 25 µg/m^3, but the WHO's Air Quality Guidelines specify a lower annual limit of 10 µg/m^3. In 2018, the $PM_{2.5}$ concentrations were higher than the annual limit value in six EU member states and two other reporting countries. The stricter WHO limit was exceeded at 70% of reporting stations, located in 29 of the 33 countries reporting $PM_{2.5}$ data.

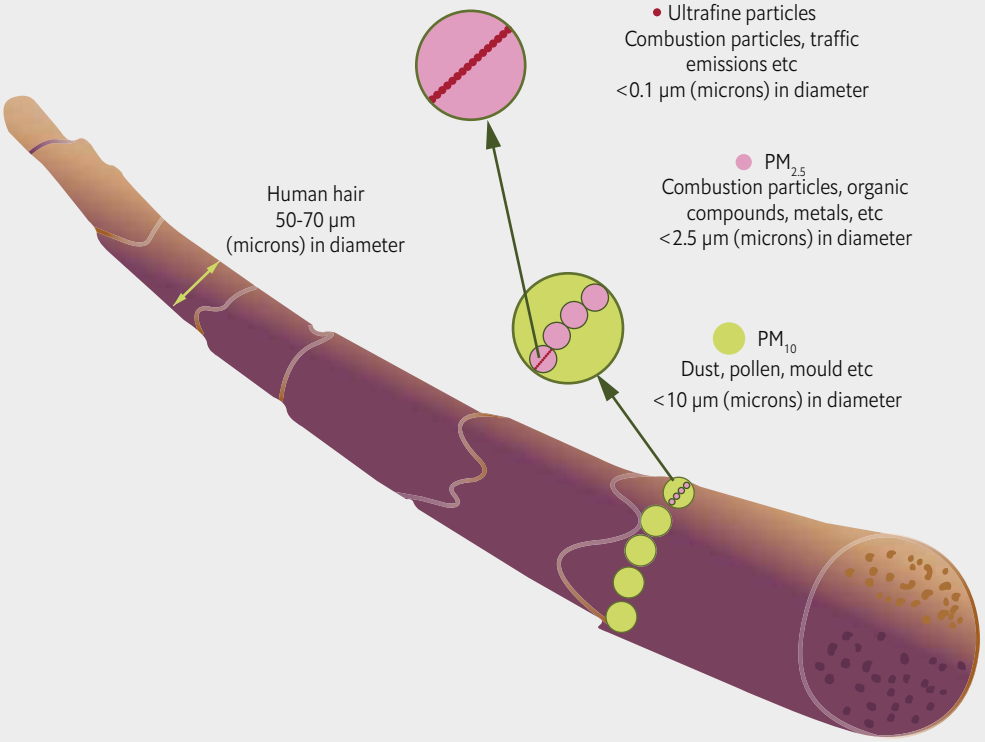


Reference data: ©ESRI | ©EuroGeographics

Source: European Environment Agency https://www.eea.europa.eu/data-and-maps/figures/pm2-5-annual-mean-in-2 and Air quality in Europe 2020 report, 2020.

[210] Ibid.
[211] WHO. Review of evidence on health aspects of air pollution: REVIHAAP project: technical report. Copenhagen: World Health Organization; 2013. Available from: http://www.euro.who.int/en/health-topics/environment-andhealth/air-quality/publications/2013/review-of-evidence-on-health-aspects-ofair-pollution-revihaap-project-final-technical-report

What is particulate matter?



"Coarse" PM (PM_{10}) has a diameter less than 10 µm: It is small enough to be inhaled and be deposited in the nose and throat, and may even reach the upper region of the lung. PM_{10} includes dust from construction sites, landfills and agriculture, wildfires and brush/waste burning, industrial sources, wind-blown dust from open lands, pollen and fragments of bacteria. It is also produced by the combustion of fossil fuels and wood.[212]

"Fine" PM ($PM_{2.5}$) has a diameter less than 2.5 µm: It is more likely to travel into and be deposited on the surface of the deeper parts of the lung (bronchiole tubes), so it has the potential to be more damaging to respiratory health than PM_{10}.[213] Some particles may cross into the bloodstream.[214] A large proportion of $PM_{2.5}$ comes from the combustion of gasoline, oil and diesel fuel by vehicles, but it is also produced by the combustion of wood (wood burners and wildfires) and power stations.[215,216]

"Ultrafine" PM ($PM_{0.1}$) has a diameter less than 0.1 µm: It is the most damaging PM because it is so small it can reach the alveoli, cross into the bloodstream and reach organs. Less is known about $PM_{0.1}$ and there are no standards for monitoring these particles in Europe. They are produced by vehicles' brakes and engines outdoors.[217,218] Levels may be even higher indoors since burning candles is associated with their generation.[219]

[212] California Air Resources Board. Inhalable particulate matter and health ($PM_{2.5}$ and PM_{10}). 2021. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health
[213] Ibid.
[214] US Environmental Protection Agency. Particulate matter (PM) basics. 2021. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics
[215] California Air Resources Board. Inhalable particulate matter and health ($PM_{2.5}$ and PM_{10}). 2021. https://ww2.arb.ca.gov/resources/inhalable-particulate-matter-and-health
[216] Smith D. The three types of particulate matter: all about PM_{10}, $PM_{2.5}$ and $PM_{0.1}$. Kaiterra; 2020. https://learn.kaiterra.com/en/air-academy/three-types-of-particulate-matter
[217] Wihersaari H, Pirjola L, Karjalainen P et al. Particulate emissions of a modern diesel passenger car under laboratory and real-world transient driving conditions. Environ Pollut. 2020;265(Pt B):114948.
[218] Karthikeyan S, Thomson EM, Kumarathasan P et al. Nitrogen dioxide and ultrafine particles dominate the biological effects of inhaled diesel exhaust treated by a catalyzed diesel particulate filter. Toxicol Sci. 2013;135(2):437-50.
[219] Zhao J, Birmili W, Hussein T et al. Particle number emission rates of aerosol sources in 40 German households and their contributions to ultrafine and fine particle exposure. Indoor Air. 2021;31:818-31.

Improvements in fuel and engine technology and the use of catalytic converters have reduced the particulate mass and carbon monoxide emitted from automotive exhausts but have increased the number and toxicity of ultrafine particles (PM0.1).[220]

Ultrafine particles are able to get through engine filters and are very damaging to health, said Professor Annesi-Maesano. They penetrate deep into the airways and can induce coughing and worsen asthma.[221]

"They reach the alveoli, and they are so small that they can cross into the blood and from the blood they go to the organs," said Professor Annesi-Maesano. "That's why pollution is related to many other diseases including neurodegenerative diseases and metabolic diseases."

According to the advisory board, Europe is not currently monitoring ultrafine particles and no safety thresholds have been set. The WHO's forthcoming update of their air quality guidelines is also not expected to mention ultrafine particulates.

Paris has only one monitoring station for fine particles in an area of 100 km^2, and there is no monitoring of ultrafine particles, Professor Annesi-Maesano pointed out. "This monitoring provides an annual mean for fine particles, but that is not representative. It is like you take a body, you put the head in a freezer and the feet in the oven and then you measure the temperature of the body.

"We need more consistent monitoring of fine particles and to introduce it to ultrafine particles."

Methane

Methane is a powerful greenhouse gas emitted by human activities, including agriculture (particularly raising of ruminant livestock), coal mining, oil and gas production and distribution and biomass burning. It also comes from natural sources such as wetlands.[222]

Methane has a direct influence on climate change, but also a number of indirect effects on human health. These include increased respiratory illnesses such as cough and pneumonia, in children living in homes where gas (which contains methane) is used for cooking.[223,224,225]

But most importantly, like NO_2, methane is an important precursor to ground-level ozone.[226] "When it comes to air pollution management, the focus is usually on local and regional pollution, because most air pollutants don't travel far outside the region where they are emitted," said Mr Borgford-Parnell. But this is not the case when it comes to methane.

[220] Schraufnagel DE. The health effects of ultrafine particles. Exp Mol Med. 2020;52:311-7.
[221] Ibid.
[222] Climate and Clean Air Coalition. Methane. https://www.ccacoalition.org
[223] Wong TW, Yu TS, Liu HJ et al. Household gas cooking: a risk factor for respiratory illnesses in preschool children. Arch Dis Child. 2004;89(7):631-6.
[224] Hölscher B, Heinrich J, Jacob B et al. Gas cooking, respiratory health and white blood cell counts in children. Int J Hyg Environ Health. 2000;203(1):29-37.
[225] Coker ES, Smit E, Harding AK et al. A cross sectional analysis of behaviors related to operating gas stoves and pneumonia in U.S. children under the age of 5. BMC Public Health. 2015;15:77.
[226] Climate and Clean Air Coalition. Methane. https://www.ccacoalition.org/en/slcps/methane

“Well-mixed greenhouse gases like methane have a long enough lifetime in the atmosphere that it actually doesn’t matter where they’re admitted on Earth. Methane emitted in Los Angeles will impact ozone formation in Monaco,” he said.

Methane is considered the second greatest contributor to climate change after CO_2. It has a much shorter atmospheric life span than CO_2, but it is much more efficient at trapping heat. Per unit of mass, the impact of methane on climate change over 20 years is 86 times greater than CO_2, and over a 100-year period it is 28 times greater.[227]

As a result, measures to tackle methane would have an immediate effect, the advisory board said. The board pointed out that if methane is reduced by 45% over the next decade, it could reduce temperature increases by 0.3˚C by the 2040s—a significant reduction that cannot be achieved through CO_2 or other decarbonisation measures.[228]

Separately, as temperatures rise, air is expected to become more stagnant due to weaker global circulation, trapping particulates and ground-level ozone in the lower atmosphere.[229] In Europe, air stagnation is most common in the Mediterranean region, which has annual stagnation frequencies in the region around 40%, followed by Scandinavia

What are well-mixed greenhouse gases?

Well-mixed greenhouse gases include carbon dioxide, methane, nitrous oxide, and the chlorofluorocarbons. They are well mixed in the atmosphere because they are long lived.

[227] Ibid.
[228] UN. Global methane assessment: benefits and costs of mitigating methane emissions. New York: United Nations; 2021. Available from: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions
[229] Climate Central. Summer heat means stagnant air. 2019. https://medialibrary.climatecentral.org/resources/summer-heat-means-stagnant-air

where stagnation frequency is near 30%. The UK and north-central Europe have stagnation frequencies around 15%.[230]

1.6.2 How indoor air pollution impacts lung health

While outdoor air pollution is claiming increasing attention, very little attention is given to indoor air quality and how our push for energy efficient buildings to tackle our carbon footprint can create issues for respiratory health. Indoor air quality is affected both by the quality of the air outside and the pollutants in the building itself, and it is an understudied area.[231]

"This is a big issue," said Mr Sanchez Martinez, "because Europeans spend about 90% of their time indoors, and the people who are more vulnerable to these kinds of exposures spend even more time indoors than the average person, so most of their exposure to air pollution happens indoors."

According to the advisory board, those most at risk include children, women and older people.

Pollutants in indoor air can irritate lungs and exacerbate asthma symptoms, and indoor air pollution has been linked with asthma, wheezing, conjunctivitis, dermatitis and eczema in children.[232]

Potential sources of indoor pollutants are heating sources, particularly wood burning stoves; natural gas leakage from cookers and gas fires; volatile organic compounds from cleaning products, air fresheners and household furnishings; as well as candles, dust mites and pet dander.[233]

Smoking also remains a leading contributor of indoor air pollution, and smoking and second-hand smoke remain responsible for a substantial portion of chronic respiratory disease–attributable disability-adjusted life years related to pollution. [234,235]

The structure of buildings can also contribute to indoor air pollution. Old buildings are more likely to be subject to damp problems, which are linked to increased risk of mould and dust mites, which can exacerbate asthma,[236,237] but new buildings are not without problems.[238]

As part of climate change mitigation efforts, building regulations place emphasis on energy efficiency but contain few specific standards for air quality.[239] As a result, they are often highly insulated with well-fitting windows, so they have little airflow, meaning pollutants get trapped inside.

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[230] Maddison J, Abalos M, Barriopedro D et al. Linking air stagnation in Europe with the large-scale atmospheric circulation. Preprint. Weather and Climate Dynamics preprint. Discussion started: 27 Jan 2021. https://doi.org/10.5194/wcd-2021-5
[231] Mendoza DL, Benney TM, Boll S. Long-term analysis of the relationships between indoor and outdoor fine particulate pollution: A case study using research grade sensors. Sci Total Environ. 2021;776:145778.
[232] Royal College of Paediatrics and Child Health. The inside story: health effects of indoor air quality on children and young people. Jan 2020. Available from: https://www.rcpch.ac.uk/resources/inside-story-health-effects-indoor-air-quality-children-young-people
[233] Ibid.
[234] San Diego State University. Smoking out sources of in-home air pollution: a new study finds that cigarette and marijuana smoking, as well as candles, cleaning products and frying food, all harm a household's air quality. ScienceDaily, 18 May 2017.
[235] Soriano JB, Kendrick PJ, Paulson KR et al. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Respir Med. 2020;8(6):585-96.
[236] Sharpe RA, Thornton CR, Nikolaou V et al. Fuel poverty increases risk of mould contamination, regardless of adult risk perception & ventilation in social housing properties. Environ Int. 2015;79:115-29.
[237] Simoni M, Lombardi E, Berti G et al. Mould/dampness exposure at home is associated with respiratory disorders in Italian children and adolescents: the SIDRIA-2 Study. Occup Environ Med. 2005;62(9):616-22.
[238] Royal College of Paediatrics and Child Health. The inside story: health effects of indoor air quality on children and young people. Jan 2020. Available from: https://www.rcpch.ac.uk/resources/inside-story-health-effects-indoor-air-quality-children-young-people
[239] Ibid.

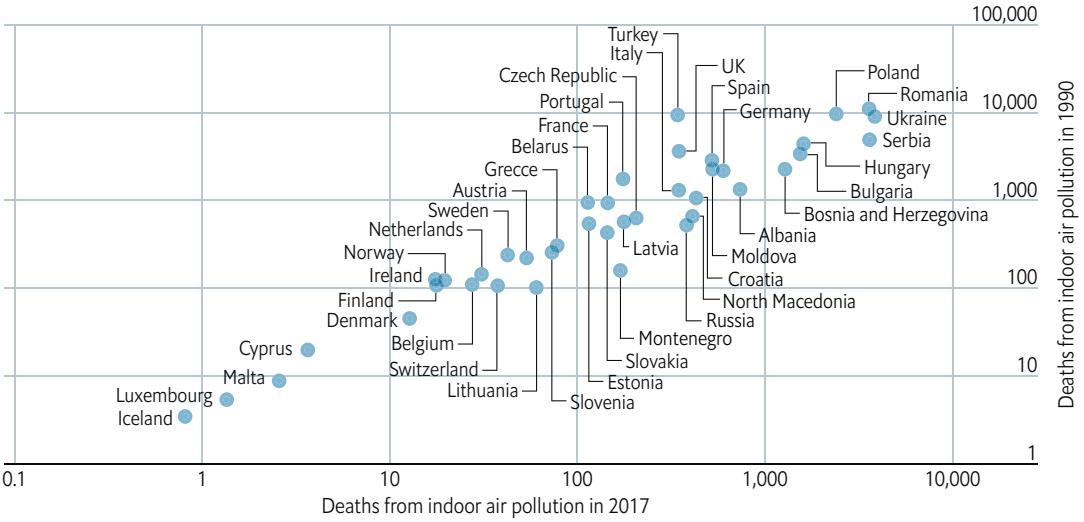
As we respond to climate change, including through the construction of more energy efficient and more air-tight homes, consideration should be given to the role of indoor air pollution on lung health to ensure there is adequate ventilation and that pollutants are not trapped inside, the advisory board said. At the moment, responsibility for dealing with indoor air pollution falls between regulators/agencies, they highlighted.

Studies by the US Environmental Protection Agency have found that indoor levels of pollutants may be two to five times—and occasionally more than 100 times—higher than outdoor levels.[240] Air quality testing of some UK homes found that ultrafine particle pollution levels were on average 3.5 times higher inside than outside, peaking at 560 times outdoor air pollution.[241] But overall, very little research has been done on the levels of indoor pollution and its effects on health (Figure 18).

More research is needed, the advisory board agreed, because at the moment, it is unclear whether the high levels of indoor air pollution that some people are exposed to are as harmful as outdoor air pollution.

Figure 18: Annual number of deaths from indoor air pollution, Europe, 1990 v 2017

The highest death rates for indoor air pollution are in former Eastern Bloc countries where households are more reliant on coal and wood burning for heating homes; log scale.



Source: Our World in Data.

[240] US Environmental Protection Agency. Why indoor air quality is important to schools. 2020. Available from: https://www.epa.gov/iaq-schools/why-indoor-air-quality-important-schools

[241] Clean Air Hub. A new study from Clean Air Day reveals that ultrafine particle pollution is on average 3.5 times higher inside the home than outside—and in one case peaked at 560 times higher than outdoors. Global Action Plan; 2019. https://www.cleanairhub.org.uk/news-stories/indoor-air-pollution-3-5-times-worse-than-outdoor-air-pollution

At the most basic level, more attention needs to be given to indoor temperatures, Mr Sanchez Martinez said. "Heatwave action plans are focused on outdoor temperatures. The relationship between outdoor temperatures and indoor temperatures in a given city, or even within a given quarter, is not direct. It's heavily influenced by the type of building, the ventilation and the use of air conditioning.

"We don't even know what temperature people are actually experiencing in their home. It's surprising how little data we have about that."

Section 2: Policy responses

Climate change is a serious threat to respiratory and wider health and so presents an urgent challenge to European countries, policymakers, healthcare systems and individuals, especially those living with pre-existing lung conditions.

Solutions must be integrated and multifaceted because climate change is driven by a complex web of interrelated factors. Our analysis and insight from our advisory board and interviewees have illustrated that for climate change action to be successful, the approach needs to be more holistic by involving all the key stakeholders and adopting a common goal to improve public health.

"The climate community, at least historically, primarily focused on trying to hit a temperature target at the end of the century, so the temperature change that happens in between has been a lesser concern," stresses Mr Borgford-Parnell. "But the path we take is critically important. We need to think of climate change as a path from today into the future and think about how the choices we make impact that path, not just for temperature change but for public health."

He added that society and policymakers cannot achieve this unless they look at "both air pollutants and greenhouse gases as an inexorably linked problem. Too often these issues are managed in silos with little systematic consideration of how choices made in one silo benefit or harm the other. You've got to manage this from a one-atmosphere perspective."

Ms Gordeljevic said the evidence regarding the health impacts of air pollution from fossil fuel burning is "really strong" since it shows a significant harm to health, even at very low air pollution exposure. "In fact, studies are increasingly finding that there is no safe level of pollution for certain pollutants at all," she added.

Most importantly, there must be a recognition that efforts focused on driving down one pollutant can have unfortunate consequences in terms of increasing levels of another. The classic example being Europe incentivising the use of diesel engines to cut carbon emissions, but there are others (see box).

James Milner, assistant professor at the London School of Hygiene and Tropical

Medicine, said, "Government departments need to work together, not in silos, as there are numerous examples of past policy measures having unintended consequences and adverse effects on health. Measures need to be considered carefully and holistically so as not to make other matters worse, for example, the rush to increase the use of diesel vehicles was beneficial for the climate, but not for air pollution and lung health."

Each person and sector is a stakeholder when it comes to climate change, both in terms of the consequences and tackling it. A combination of mitigation (dealing with the causes) and adaptation strategies (looking at how to reduce the effects on lung health) can help address climate change and its impact on lung health, but effective implementation will depend on cooperation through integrated responses that link them.

Our research, advisory board discussions and interviews have highlighted the opportunities and policy priorities that exist for some key stakeholder groups.

Unfortunate consequences of siloed efforts to tackle climate change

Transportation and its impact: diesel engines' not so hidden secret

In the 1990s, European governments introduced tax incentives to encourage drivers to shift from petrol to diesel vehicles, based on "carbon accounting". But the increase in diesel vehicles dramatically increased NOx and particulate emissions in Europe as a consequence, which has health impacts.

Policymakers involved in those decisions interviewed many years later said that they did not know that the move to diesel engines would increase air pollution, said Nathan Borgford-Parnell, scientific affairs co-ordinator, Climate and Clean Air Coalition.

"The scientific community who worked in this field for many years are all deeply confounded by that answer, because the fact is we did know it was going to increase air pollution," he said.

"The decision was made on the basis of the long-term climate benefit and did not take account of the wider near-term impact on air quality and public health, and that's because most countries, particularly developed countries, manage air pollution, and manage climate change in silos within their governments."

Traditional culture and its impact: saunas in Finland

In 2020, Finland's sauna culture was added to UNESCO's representative list of the intangible cultural heritage of humanity, sitting alongside Indian yoga and the Argentinian tango.[242] But it has a cost that the Finns are only realizing.

The Finnish government has a climate mitigation plan that it reviews roughly every three years. Like the decision to incentivise diesel vehicles, the original plan was based exclusively on maximizing reductions of carbon dioxide emissions. Before the last review in 2018, new environmental impact assessment legislation required that the government conduct an internal assessment for any new major legislation and that it assess not only the air quality impacts but also the consequences on public health. Most households in Finland have or have access to a sauna within their building,[243] and wood burning stoves for saunas had been incentivised in the previous climate plan. At the 2018 review, they found something quite "astounding", said Mr Borgford-Parnell. "The newly required impact assessment showed that particulate matter air pollution coming out of those saunas was going to kill about 248 people a year." As a result, he added: "They conducted a number of wood burning sauna upgrades and education campaigns to help people burn better and more efficiently to reduce the smoke coming out of the saunas."

[242] UN. Finnish sauna added to UNESCO's Cultural Heritage List. https://unric.org/en/finnish-sauna-added-to-unescos-cultural-heritage-list/
[243] Statistics Finland. Housing. https://stat.fi/tup/suoluk/suoluk_asuminen_en.html

2.1 Policy interventions at the European and national level

Ultimately action against climate change and air pollution must be global if respiratory health is to be optimised because emissions produced in one region of the world can and will impact other regions. Action is also in line with the UN's sustainable development goals.[244]

"It impacts all across the world," explained Professor Kelly. "Ultimately, if we're acting in Europe, but China, India and the US are not, we're still going to have global warming and all its effects."

While Europe cannot prevent global warming alone, it is important for Europe to be seen to act on climate change by reducing emissions as quickly and as effectively as possible and to go beyond existing international standards and targets. "We're setting an example, we're demonstrating what works and what doesn't work and we hope that others will follow that lead," he said.

Speed up progress towards the zero-carbon economy by getting there earlier

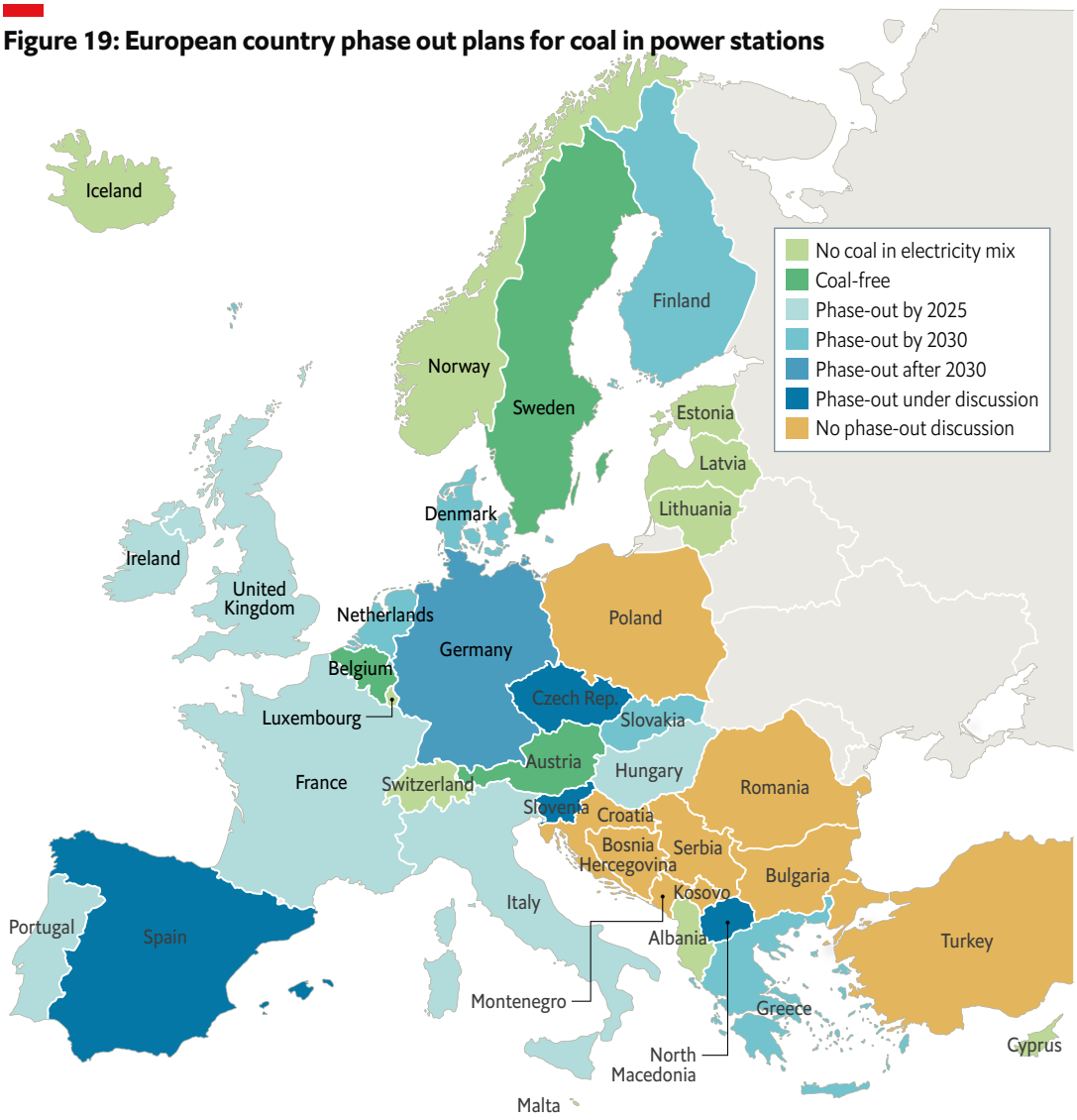
Europe aims to be the first climate-neutral continent by 2050 by moving to an economy with net-zero greenhouse gas emissions. This is in line with the EU's commitment to global climate action under the Paris Agreement, which aims to control the global temperature increase to 2°C and preferably 1.5°C above pre-industrial levels.[245] The EU has also put forward a plan to cut greenhouse gas emissions to 55% of 1990 levels by 2030.[246]

The European Green Deal was presented by the EU in 2019; it and the EU Action Plan "Towards Zero Pollution for Air, Water and Soil" provide the strategy and framework to achieve these ambitions,[247,248] supported by other EU key policies that highlight risks to respiratory health, such as the EU's Europe's Beating Cancer Plan.[249] Our advisory board saw the European Green Deal as a "tall order" and was concerned about how it will be enforced. Ultimately, whether these goals are achieved will rely on governments setting national action plans that are ambitious enough.

The targets are for Europe and not national targets, said Nicolás González Casares, MEP, Spain (Spanish Socialist Worker's Party, Group of the Progressive Alliance of Socialists and Democrats), because some countries such as Poland and Hungary have economies more reliant on coal and thus face a bigger challenge. "The target is to get to climate neutrality by 2050 together, so maybe countries like Poland can have more time to become climate neutral at a national level than the 2050 target."

[244] UN. Goal 13. Take urgent action to combat climate change and its impacts. https://sdgs.un.org/goals/goal13
[245] UN Framework Convention on Climate Change. The Paris Agreement. 2020. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[246] European Commission. 2030 climate target plan. Available from: https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en
[247] European Commission. A European Green Deal. 2021. Available from: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[248] European Commission. EU action plan: towards zero pollution for air, water and soil. 2021. Available from: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827
[249] European Commission. Europe's Beating Cancer Plan. 2021. Available from: https://ec.europa.eu/health/sites/default/files/non_communicable_diseases/docs/eu_cancer-plan_en.pdf#:~:text=Europe%E2%80%99s%20Beating%20Cancer%20Plan%20is%20a%20key%20pillar,structural%20improvements%20for%20a%20more%20sustainable%20cancer%20pathway

Figure 19: European country phase out plans for coal in power stations



Source: Europe Beyond Coal; https://beyond-coal.eu/wp-content/uploads/2021/03/Overview-of-national-coal-phase-out-announcements-Europe-Beyond-Coal-22-March-2021.pdf.

Many countries are falling short in terms of the ambition and implementation of their climate change action plans, and climate change activists are taking these governments to court to force them to take stronger action.

In 2019, the supreme court in the Netherlands upheld a ruling requiring the government to slash GHG emissions by at least 25% of 1990 levels by the end of 2020 after environmentalists argued that progress on the 2030 target was too slow. By the end of 2018, emissions were down only 15% on 1990 levels.[250]

[250] Netherlands climate change: Court orders bigger cuts in emissions. BBC News, 20 December 2019.

In 2019, Germany wrote the 2030 55% target into law, but environmentalists argued that the climate protection measures proposed by the government were not tough enough and took the government to court. In April 2021, Germany's supreme constitutional court agreed and said the government had until the end of next year to improve its Climate Protection Act, passed in 2019, and to ensure it met 2030 greenhouse gas reduction goals more immediately.[251]

In February 2021, a French court ruled that the government must do more on climate change because it was missing its targets.[252]

Complaints have also been brought by environmental groups in Spain, Italy and Poland: in Spain because the government plans to cut emissions by just 23% by 2030[253] and in Italy because the 2030 target has been set at 33%.[254] In Poland, a court has been asked to find that the Polish government must commit to at least 60% reduction in GHG emissions (on 1990 levels) by 2030 and climate neutrality by 2043.[255]

"There has been a huge change in attitude, amongst the public and politically, in regards to climate change, and I expect us to make great progress and be seen as a leader in the world in reducing emissions," said Sean Kelly, MEP, Ireland (Fine Gael, Group of the European People's Party). More people have become more aware of the issue of climate change, led by young people such as Greta Thunberg, and their actions and the associated publicity have created even greater public awareness and demand for more action.

When the climate package was presented in European parliament with its targets, young people were dissatisfied. "[They] told us it wasn't enough, so we've revisited it, and upped the ante considerably."

Europe should be looking at being "a genuine leader in the world, in every sense," said Mr Kelly, who is also one of 22 MEPs who are part of the MEP Lung Health Group,[256] who are exploring legislative and non-legislative measures to promote lung health in Europe.[257] One of the group's aims is to contribute policy input across diverse areas such as health, environment, housing, energy, transport and air quality.

Actions on emissions must be across all sectors

Making a zero-carbon economy a reality requires action across all sectors, the EIU advisory board agreed, both in terms of adaptation and mitigation. All parts of society and economic sectors must play a role, from the power sector to industry, transport, buildings, agriculture and forestry (Figure 20). Our advisory board stressed that there need to be "big steps in lots of different areas".

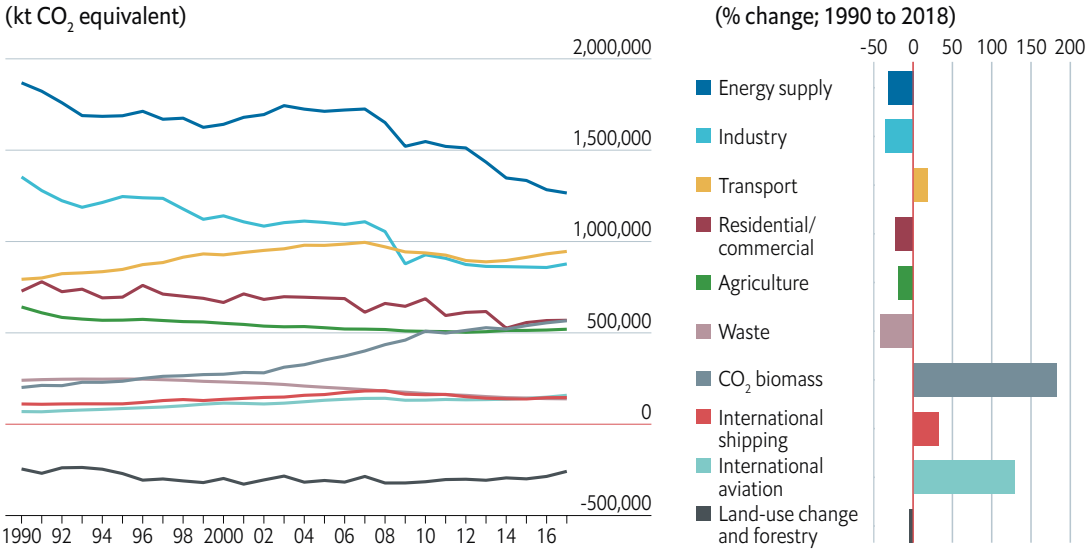
"We have to look at every sector, we can't take a single-sector approach and say we will just focus on power or transport because

[251] Connolly K. 'Historic' German ruling says climate goals not tough enough. The Guardian, 29 Apr 2021.
[252] El Gharib S. France found guilty of climate inaction in 'historic victory' for activists. Global Citizen, 3 Feb 2021.
[253] Parra A. Activists take Spain's government to court over climate plan. ABC News, 17 Jun 2021.
[254] Giuffrida A. Italian climate activists sue government over inaction. The Guardian, 5 Jun 2021.
[255] Campbell M. Polish people take their government to court as climate impacts worsen. EuroNews, 10 Jun 2021.
[256] MEP Lung Health Group (https://mk0ersnetorgsavg5whs.kinstacdn.com/wp-content/uploads/2021/02/MEP-Lung-Health-Group-flyer.pdf) and European Respiratory Society (https://www.ersnet.org/advocacy/mep-lung-health-group/)
[257] European Respiratory Society. https://www.ersnet.org/advocacy/mep-lung-health-group/

that's the main culprit," said Anne Stauffer, director for strategy and campaigns, The Health and Environment Alliance. "We have to look at climate change and air pollution from a holistic perspective, and that means that all of the sectors have to contribute to reducing emissions."

The advisory board emphasised that implementing the Kigali Amendment to the Montreal Protocol should be a priority because it will have a rapid impact. The Kigali Amendment aims to phase-down the use of high global warming–potential hydrofluorocarbons (HFCs) by encouraging the use of low global warming–potential alternatives. The phase-down of HFCs is already well advanced in some sectors, such as in refrigeration and air conditioning, but the amendment acknowledges that some residual use of these chemicals may be required in some sectors, for example in healthcare, which is why it is a phase-down rather than a phase-out strategy.[258]

Figure 20: Greenhouse gas emissions in Europe by sector, 1990-2018



Source: European Environment Agency. https: //www.eea.europa.eu/data-and-maps/daviz/ghg-emissions-by-aggregated-sector-5#tab-dashboard-02.

There has been a move across Europe over the last two decades to burn more wood in power stations and homes,[259] promoted by the push to reduce use of fossil fuels and a mistaken view that wood, as a renewable resource, is somehow climate friendly.

Many European power stations have converted from coal to burning biomass, mostly wood in pellet or chip form. While the switch to biomass led to a 7% decrease in SO_2 and 1% decrease in NOx emissions between 2005 and 2017, it was also associated with an 11% increase in $PM_{2.5}$ emissions, a 7% increase in coarse particulate matter (PM_{10}) and a 4% increase in volatile organic compounds.[260]

[258] OzonAction. Introduction to the Kigali Amendment. Available from: https://wedocs.unep.org/bitstream/handle/20.500.11822/26869/7876FS01Intro_EN.pdf?sequence=1&isAllowed=y
[259] WHO. Residential heating with wood and coal: health impacts and policy options in Europe and North America. Copenhagen: WHO Regional Office for Europe; 2015. Available from: https://www.euro.who.int/__data/assets/pdf_file/0009/271836/ResidentialHeatingWoodCoalHealthImpacts.pdf
[260] European Environment Agency. Renewable energy in Europe: key for climate objectives, but air pollution needs attention. Luxembourg: Publications Office of the European Union; 2019. Available from: https://www.eea.europa.eu/publications/renewable-energy-in-europe-key

Wood burning in homes has also become much more popular in Europe. It occurs not just in homes in low- and middle-income countries where it may provide the only source of heat, but increasingly in higher income countries for lifestyle and aesthetic reasons (such as *hygge*), and because it is viewed as a renewable fuel. All this additional wood burning is driving up particulate emissions.

For example, in the UK, decreases achieved in particulate matter emissions from other sources have been partially offset by increases in emissions from residential burning, official statistics show. Annual $PM_{2.5}$ emissions from domestic wood burning more than doubled between 2003 and 2019, reflecting the increasing popularity of solid fuel appliances in the home such as wood burning stoves. Domestic wood burning accounted for 38% of $PM_{2.5}$ emissions in the UK in 2019–this is more than three times the amount attributed to transport (12%).[261] Yet a survey (published in 2020) found that just 8% of UK households burnt wood indoors and that 68% were in urban areas.[262]

Act on methane and not just carbon

The advisory board and interviewees highlighted that methane is the second biggest contributor to climate change after CO_2 and that tackling it is essential in order to meet 2030 and 2050 climate goals. Methane has a much shorter atmospheric life span than CO_2, but it is much more efficient at trapping heat (per unit of mass, the impact of methane on climate change over 20 years is 86 times greater than CO_2), so tackling it would have immediate results.[263]

If methane is reduced by 45% over the next decade, it could reduce temperature increases by 0.3°C by the 2040s,[264] and the International Energy Agency estimates that this level of reduction can be achieved at no net cost.[265]

Reducing methane emissions is one of the priority initiatives in the European Green Deal. The EU adopted a methane strategy in October 2020, which focuses on reducing methane emissions in the energy, agriculture and waste sectors since these areas account for almost the entirety of anthropogenic methane emissions. As part of this, the European Commission is developing a legislative proposal to prevent methane leaks in the energy sector. This will include binding rules on monitoring, reporting, verification, leak detection and repair in the energy sector and will consider rules on routine venting and flaring.[266]

The strategy could be "strengthened dramatically" around air quality and how

[261] UK Department for Environment, Food and Rural Affairs. National statistics: emissions of air pollutants in the UK—particulate matter (PM_{10} and $PM_{2.5}$), 2021. Available from: https://www.gov.uk/government/statistics/emissions-of-air-pollutants/emissions-of-air-pollutants-in-the-uk-particulate-matter-pm10-and-pm25
[262] Kantar. Burning in UK Homes and Gardens Research Report, Department for Environment, Food and Rural Affairs. 2020. Available from: https://uk-air.defra.gov.uk/library/reports?report_id=1014
[263] Climate and Clean Air Coalition. Methane. https://www.ccacoalition.org/en/slcps/methane
[264] UN. Global methane assessment: benefits and costs of mitigating methane emissions. 2021. Available from: https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions
[265] European Commission. Methane emissions. https://ec.europa.eu/energy/topics/oil-gas-and-coal/methane-emissions_en#:~:text=Methane%20emissions%201%20Preventing%20methane%20leaks%20in%20the,...%204%20Partners%20and%20initiatives.%20...%205%20Documents
[266] European Commission. Methane emissions. https://ec.europa.eu/energy/topics/oil-gas-and-coal/methane-emissions_en#:~:text=Methane%20emissions%201%20Preventing%20methane%20leaks%20in%20the,...%204%20Partners%20and%20initiatives.%20...%205%20Documents

methane impacts health, said Mr Borgford-Parnell. "Making the explicit links to public health brings in an additional set of stakeholders who may not have felt like they have any reason to interact with that strategy, and potentially could really strengthen the political will and ambition to address methane emissions within the EU."

Act on HFCs using the Kigali Amendment

Certain chemicals such as HFCs have very strong greenhouse gas warming potential. HFCs are commonly used in air conditioners, refrigerators, aerosols, foams and other products and were introduced as substitutes for chlorofluorocarbons and other substances that were harmful to the ozone layer, which were being phased out under the Montreal Protocol.[267]

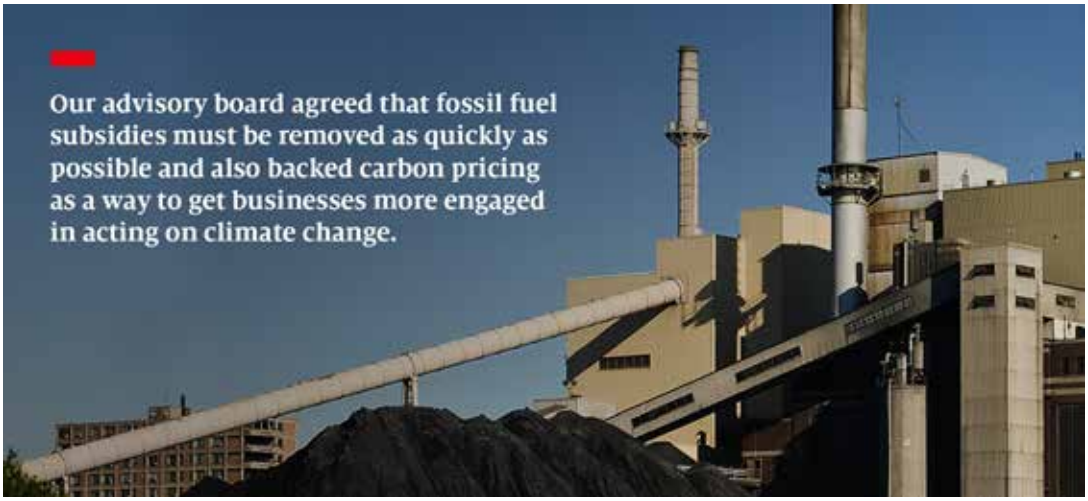
The Montreal Protocol could be seen as the greatest success story of environmental cooperation in history and perhaps the most successful international accord ever signed because it has two special mechanisms: a multilateral fund that provides financial and technical support for developing countries to comply with their commitments and a unique non-compliance procedure focused on amicable solutions and assistance rather than naming and shaming or punishment.[268]

The Kigali Amendment to the Montreal Protocol encourages use of low global warming–potential alternatives to high global warming–potential HFCs to reduce consumption and emissions of these chemicals.[269] The aim is to phase-down the use of HFCs by over 80% by 2047 to avoid up to 0.5 °C increase in global temperature on pre-industrial levels by the end of the century.[270] Low global warming–potential alternatives are already in widespread use in some sectors, but in others some residual use of HFCs may be required, which is why the Kigali Amendment is for a phase-down rather than a phase-out.[271] The phase-down of HFCs will provide significant environmental benefits.

The phase-down of these chemicals is not quite complete in the EU and elsewhere as some countries are still lagging, said Mr Sanchez Martinez. "There is not a lot of these chemicals in terms of tonnes, but because they're so powerful in their greenhouse gas potential, eliminating them quickly and everywhere will have a very measurable impact.

"It seems to me to be one of the most actionable pieces of international climate policy because everything else is voluntary," he said. "This climate policy is legally binding in most countries."

[267] UN. What's next for the Kigali deal to curb potent greenhouse gases? 20 Oct 2016. https://www.unep.org/news-and-stories/press-release/whats-next-kigali-deal-curb-potent-greenhouse-gases
[268] Ibid.
[269] OzonAction. Introduction to the Kigali Amendment. https://wedocs.unep.org/bitstream/handle/20.500.11822/26869/7876FS01Intro_EN.pdf?sequence=1&isAllowed=y
[270] UN. The Montreal Protocol evolves to fight climate change. https://www.unido.org/our-focus-safeguarding-environment-implementation-multilateral-environmental-agreements-montreal-protocol/montreal-protocol-evolves-fight-climate-change
[271] OzonAction. Introduction to the Kigali Amendment. https://wedocs.unep.org/bitstream/handle/20.500.11822/26869/7876FS01Intro_EN.pdf?sequence=1&isAllowed=y



Remove fossil fuel subsidies and price carbon effectively

Our advisory board agreed that fossil fuel subsidies must be removed as quickly as possible and also backed carbon pricing as a way to get businesses more engaged in acting on climate change. Policies against burning fossil fuels and against creation of fossil fuels should be "at the top", the advisory board stressed.

The European Commission is currently revising its Energy Taxation Directive, last updated in 2003, which lays down the rules for the taxation of energy products used as motor fuel, heating fuel and electricity.[272] An evaluation in 2019 found the directive was no longer aligned with the EU's regulatory framework and policy objectives in the area of climate and energy so does not promote emission reductions, energy efficiency, or alternative low carbon/sustainable fuels.[273] There are a wide range of sectorial exemptions and reductions applied by member states which incentivise the use of fossil fuels, for example, a tax exemption for fuel used in international aviation and maritime transport. The current directive also does not provide sufficient incentives for investments in clean technologies.[274,275,276]

The European Commission is encouraging member states, as part of their national covid-19 recovery efforts, to design appropriate green taxes to raise revenue and remove fossil fuel subsidies.[277]

[272] European Commission. European Green Deal: what role can taxation play? 2021. https://ec.europa.eu/taxation_customs/commission-priorities-2019-24/european-green-deal-what-role-can-taxation-play_en
[273] European Commission. Commission staff working document. Evaluation of the Council Directive 2003/96/EC of 27 October 2003 restructuring the community framework for the taxation of energy products and electricity. 2019. https://ec.europa.eu/taxation_customs/sites/default/files/energy-tax-report-2019.pdf
[274] European Commission. European Green Deal: what role can taxation play? 2021. https://ec.europa.eu/taxation_customs/commission-priorities-2019-24/european-green-deal-what-role-can-taxation-play_en
[275] European Commission. Commission staff working document. Evaluation of the Council Directive 2003/96/EC of 27 October 2003 restructuring the community framework for the taxation of energy products and electricity. 2019. https://ec.europa.eu/taxation_customs/sites/default/files/energy-tax-report-2019.pdf
[276] European Commission. Green taxation—in support of a more sustainable future. https://ec.europa.eu/taxation_customs/green-taxation-0_en
[277] Ibid.

In parallel, the EU is also planning to introduce a carbon border adjustment mechanism for certain sectors. Under this mechanism, the price of imports would reflect more accurately their carbon content and would ensure that the EU's green objectives are not undermined by production relocating to countries with less ambitious climate policies. It would also ensure that EU companies are not undercut by companies based outside the EU with less stringent climate change regulations.[278]

The EU already has its own internal EU Emissions Trading Scheme (ETS), which covers around 40% (around 1.6bn tonnes) of European emissions, and prices carbon by the tonne, recently increasing above €50 per tonne for the first time.[279]

Mr Casares said: "Higher carbon pricing provides a stimulus for industries to become greener, but it can also be an obstacle for some big industries in global competitiveness, such as cement and steel, which cannot move so fast as their transition is more difficult."

Applying carbon pricing to imported goods is also important, he said. "We are buying products from China still with a high footprint in CO_2 without carbon pricing, so this is also about the level playing field. It is about balance for Europe and stimulating China to reduce emissions."

Mr Casares added that the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow in November 2021 could provide an opportunity to address carbon markets on the international stage. Signatories to the Paris Agreement agreed under Article 6 to set up cooperative mechanisms on climate change and, in particular, to establish an emissions trading system, which could help lead to a global price on carbon.[280] Countries with low emissions would be allowed to sell their remaining allowance to larger emitters, with an overall cap of GHG emissions, ensuring their net reduction. Supply and demand for emissions allowances would lead to the establishment of a global carbon price, and countries exceeding their allowances would bear the costs of global warming. However, the exact mechanism of how this will work is still under negotiation.

It is anticipated that GHG emissions would undergo a strong decline under this flexible approach, which would also encourage innovative and cleaner technologies and an overall transition towards a low-carbon economy.[281]

The EU and many national governments continue to heavily subsidise fossil fuels; doing away with these subsidies is "crucial", said Mr Sanchez Martinez. "This is something that the EU and the European Commission want to tackle but it is a political hot potato because this will fall disproportionally on certain groups, for example, farming."

[278] European Commission. Commission launches public consultations on energy taxation and a carbon border adjustment mechanism. 23 Jul 2020. https://ec.europa.eu/taxation_customs/news/commission-launches-public-consultations-energy-taxation-and-carbon-border-adjustment-mechanism_en
[279] Schroders. What does a €50 carbon price mean for European companies? 19 May 2021. https://www.schroders.com/en/insights/economics/what-does-a-50-carbon-price-mean-for-european-companies/
[280] Swedish Energy Agency. Article 6 of the Paris Agreement. 18 Jun 2021. http://www.energimyndigheten.se/en/cooperation/swedens-program-for-international-climate-initiatives/cooperationunder-the-parisagreement/article-6-of-the-paris-agreement/
[281] International Chamber of Commerce. Article 6: what is it and why is it important? 18 Jul 2019. https://iccwbo.org/media-wall/news-speeches/article-6-important/

Focus on electricity and improve interconnectivity

Europe's reliance on clean renewable energy will increase as it moves towards its climate targets, so it makes sense to encourage greater use of electricity within homes and businesses, experts told the EIU. In 2018, nearly half (46%) of the net electricity generated in the EU came from combustible fuels, such as natural gas, coal and oil.[282]

Mr Kelly said improving interconnectivity of electricity grids across Europe was important in the future as Europe moved from transitional fuels (such as natural gas, nuclear power, biomass and hydrogen) to renewables, enabling the benefits of solar power from southern Europe and wind power from northern Europe to be maximised. "When the wind isn't blowing in Ireland, it could be blowing in France. If we are interconnected, Ireland would be able to get the surplus wind from France and vice versa," he said.

Sandra Cavalieri, urban health initiative coordinator at the Climate and Clean Air Coalition, pointed out that even low-income countries were acting. In Cote d'Ivoire, where they have natural gas, they are using it in power plants to generate electricity. "The switch to renewable electricity will be much faster if all the machines are electric," she said.

Invest and support green innovation and technology

Our research and insight from the advisory board and interviewees highlighted that it is vital for the EU and national governments to support and invest in renewable energy and green innovation. At the same time as putting in place legislation, the EU and national governments must incentivise industry to reduce emissions, move to green power and become more climate friendly.

The EU has dedicated €1.8trn to a post-covid-19 recovery fund to help EU members rebuild after the pandemic,[283] of which 37% will be spent on climate-related measures.[284]

Efforts to end the use of fossil fuels are expected to create many new jobs in new "green" industries such as the production, maintenance and installation of solar panels and wind turbines, but at the same time, existing jobs in industries that extract fossil fuels (such as coal) will be lost.

"Some jobs are inevitably going to either go or change, but I think we will end up creating more jobs than are lost," said Mr Kelly. He added that there would be an EU "transition fund" to help people who lost jobs to upskill and find new employment.

There are going to be "winners and losers", and avoiding ensuring some people don't lose out over their whole working life will be a challenge, Mr Casares said. "We can provide a lot of money, but we cannot be sure that this money is going to help these people."

There will also be divisions over the ecological impact of the technological transition, particularly the use of land for solar panels and wind turbines, he added.

[282] Eurostat. Electricity generation. 2020. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_production,_consumption_and_market_overview#Electricity_generation
[283] European Commission. Recovery plan for Europe. 2021. Available from: https://ec.europa.eu/info/strategy/recovery-plan-europe_en
[284] European Commission. NextGenerationEU: questions and answers on the Recovery and Resilience Facility. 16 Jun 2021. Available from: https://ec.europa.eu/commission/presscorner/detail/en/QANDA_21_3014

2.2 Policy interventions at the environmental and local level

Local regions, cities and towns can do much to improve air quality and the respiratory health of their populations by acting on emissions, although maximizing the benefits may require action on policy and infrastructure at a national level. Improving air quality by reducing emissions will also contribute towards the European drive to reduce GHG emissions by 55% by 2030 and achieve a "net-zero" economy by 2050.

The advisory board highlighted the importance of improving outdoor spaces in urban environments to encourage people to exercise and travel by bicycle or foot. This will not only help cut emissions, it will encourage active transport and physical activity to improve people's respiratory, cardiovascular and overall health.

Again, as with European and national policies, this requires a holistic approach, embedding action on climate changes into local policies such as transport, planning and buildings, and recreation, with the overall goal being to improve public health.

Encourage active transport

There was a consensus among the advisory board and the interviewees that encouraging active transport will benefit both respiratory health and efforts against climate change.

"Getting people out of cars and instead walking and cycling will mean they are more physically active, which will improve lung health, and it will also reduce greenhouse gas emissions," said Dr Milner.

Ms Gordeljevic said, "The best thing for human health and for the climate is to change cities into places where active mobility is prioritised, so where the infrastructure for walking and cycling is a key component."

Studies have shown the benefits of more cycling in cities on human health, even when pollution and the risks of accidents were taken into account, with benefits increasing with age.[285,286]

[285] Tainio M, de Nazelle AJ, Götschi T et al. Can air pollution negate the health benefits of cycling and walking? Prev Med. 2016;87:233-6.
[286] Public Health England. Cycling and walking for individual and population health benefits: a rapid evidence review for health and care system decision-makers. 2018. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/757756/Cycling_and_walking_for_individual_and_population_health_benefits.pdf

This makes promoting active transport a "no brainer," Ms Stauffer said.

The advisory board pointed out that other European cities could learn much from Copenhagen: it is one of the most cycling friendly cities in the world.[287] There are more bikes than inhabitants, and the city has been designed around making cycling the best form of transportation. There are 382 km of cycle tracks, including innovative bridges, which form cycling superhighways across the city, and traffic lights are coordinated in favour of cyclists during rush hour. In 2019, 49% of all commuter trips were by bicycle.[288]

This infrastructure is key to why Copenhagen is also one of the safest places to be a cyclist. Between 2006 and 2016, there was an increase in cyclists' sense of safety—from 53% to 76%. But the city council wants to see that increase to 90% by 2025, by which time it also wants the city to become carbon neutral.[289]

Discourage traffic but implement low emission and congestion zones with care

Although low emission zones (Figure 21) and congestion charging were not designed to address climate change, they have the potential to reduce air pollution, the advisory board pointed out. But lessons from London show that it is important that these policies are aligned with others that encourage and enable commuters in private vehicles to switch to active transport or use public transport powered by clean energy.

Studies showed that when the congestion charge was introduced in London in 2003, it led to a steep rise in NO_2 emissions.[290,291]

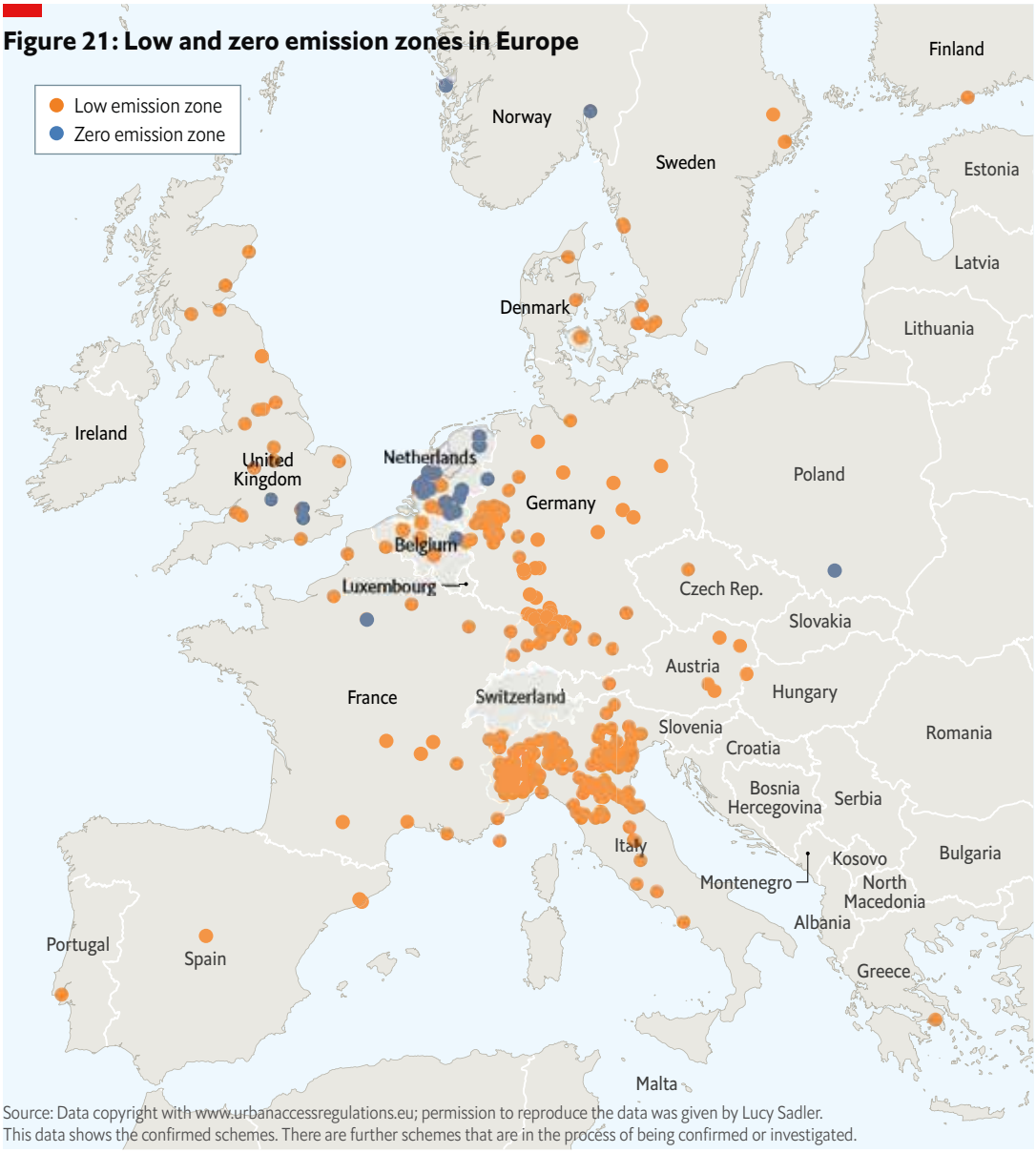
"Overnight, 70,000 fewer vehicles came into London," said Professor Kelly, who conducted some of the studies. "Congestion did decrease in London for a few years, and average speeds increased by several miles an hour, but at the same time pollution got worse."

The increased pollution resulted from people switching to public transport and taxis: bus travel flows increased by 22% and taxi flows increased by 21%. The buses and taxis were exempt from the congestion charge and ran on diesel, which pushed up NO_2 levels. However, levels of CO, NO and PM_{10} have fallen since the charge was introduced.[292]

Electric vehicles are also exempt from the London congestion charge. While this may benefit local air quality, exempting electric vehicles is "absurd" if these policies are to be used to tackle climate change, said Professor Annesi-Maesano. "You need to produce the electricity to charge the battery? How do you do that? The old way with fossil fuel or nuclear!" So the emissions are simply being shifted somewhere else.

[287] Coya. Global bicycle cities indexes 2019. https://www.coya.com/bike/index-2019
[288] VisitCopenhagen. Copenhagen's bike culture. 2021. https://www.visitcopenhagen.com/copenhagen/activities/copenhagens-bike-culture
[289] World Economic Forum. What makes Copenhagen the world's most bike-friendly city? 5 Oct 2018. Available from: https://www.weforum.org/agenda/2018/10/what-makes-copenhagen-the-worlds-most-bike-friendly-city/
[290] Kelly F, Anderson HR, Armstrong B et al. The impact of the congestion charging scheme on air quality in London. Part 1. Emissions modeling and analysis of air pollution measurements. Res Rep Health Eff Inst. 2011;(155):5-71.
[291] Green CP, Heywood JS, Paniagua MN. Did the London congestion charge reduce pollution? Reg Sci Urban Econ. 2020;84:103573.
[292] Ibid.

Figure 21: Low and zero emission zones in Europe



Source: Data copyright with www.urbanaccessregulations.eu; permission to reproduce the data was given by Lucy Sadler.
This data shows the confirmed schemes. There are further schemes that are in the process of being confirmed or investigated.

Increase green space in cities

There are clear benefits of greening cities in terms of reducing air pollution, and there are also benefits for respiratory health, although these are less-well established because, while decreased pollution will benefit them, encouraging people to be outdoors and being around a higher density of plants will increase exposure to pollen and other aeroallergens.

Green space can mitigate the negative effects of air pollution, excessive noise, heat and flooding and can help to bind communities

together, reducing loneliness. Disadvantaged groups appear to gain a larger health benefit, helping to reduce socioeconomic-related inequalities.[293]

One city that developed an ambitious green plan to increase the area devoted to green spaces is Barcelona. The city currently has only 6.82 m^2 of green space per capita compared to the 26 m^2 per capita target recommended by the EU.[294] The city is increasing the number of street trees and urban gardens and is connecting green spaces with green corridors to encourage people to do more walking and cycling.[295]

Under its "superblock" plan, one in three streets in the Eixample district will become a green hub. At the intersections of these green hubs, there will be 21 new squares so that all local residents will have a green hub or square within a maximum of 200 m of their home.

"They're transforming former intersections into small green spaces where people can meet, chat and spend time, and they're helping to mitigate climate change and improving the air," Ms Stauffer said.

Monitor emissions and issue warnings when pollutant levels are high

Accurate, localised real-time data can aid understanding of the links between climate change/air pollution and respiratory disease and can aid management, but the current level of air quality monitoring is insufficient. What data are collected are difficult to find, according to both the advisory board and interviewees.

The current compulsory monitoring of emissions is "too light", focused on averages rather than peaks, and there are too few monitoring stations in large cities, said

[293] Public Health England. Improving access to greenspace. A new review for 2020. London: Public Health England; 2020. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/904439/Improving_access_to_greenspace_2020_review.pdf
[294] Oppla. Barcelona: nature-based solutions (NBS) enhancing resilience to climate change. 2021. Available from: https://oppla.eu/casestudy/17283#:~:text=The%20City%20of%20Barcelona%2C%20with%20its%20Green%20Infrastructure,for%20local%20people.%20With%20a%20similar%20vision%20
[295] Ibid; and Ajuntament de Barcelona. Towards superblock Barcelona. 11 Nov 2020. Available from: https://ajuntament.barcelona.cat/premsa/wp-content/uploads/2020/11/201111-DOSSIER-Superilla-Barcelona-EN.pdf

Professor Annesi-Maesano. As a consequence, the conducted assessments are not representative of people's real exposure. There is also no monitoring of $PM_{0.1}$ levels, she added.

Data from official monitoring is collated by the EEA, although some advisory board members pointed out that these data are not always easy to find.

Mr Sanchez Martinez said, "The European Environment Agency's infrastructure for data collection and data sharing is solid, particularly in the case of air pollution, where data collection happens in almost real time and data are accessible through the EEA website." But the EEA plans to put it together into a European Environmental Health Atlas, so it's all collected in the same place and is easier to find, he said.

Experts would like to see data on pollen levels integrated with that on air pollution. "Pollen is also a pollutant in the air," said Ms Stauffer, "it's just that in terms of the regulation, it's been treated separately, but as more and more people suffer from allergies and the allergy season grows longer, it's definitely something we need to look into."

People should then be alerted to rises in pollen, pollutants and temperatures that could put their heath at risk. "Health alerts are very important, so that people can make informed choices when there are peaks," she said. "This is a key issue for respiratory patients, and there needs to be some guidance and harmonisation on these health advisories on the kind of information that is provided in these alerts."

While better data can increase understanding of the location of pollution hotspots and increase public engagement, it is not the be all and end all. The lack of it should not be used as an excuse for inaction against pollution and climate change, and a desire for data should not distract from tackling the core issues of improving air quality.

"We get a lot of people saying, 'we can't act on air pollution because we don't have any monitoring', but [monitoring] is not essential," said Tiy Chung, communications officer at the Climate and Clean Air Coalition.

"There are certain things that go on within a community that indicate an air pollution problem," he added. "If you've got all diesel engine trucks running around in your town, you know that you've got a problem, if you've got people reliant on burning wood for heating and cooking, then you know you've got a problem. Data just help pinpoint where and how big that problem is."

"Hyper-localised air pollution monitoring has extreme diminishing returns in my opinion," said Mr Borgford-Parnell. "As a tool for increasing awareness, there may be value, but when it's used by profit-minded groups as a way to try to convince consumers that it's primarily up to them to solve this issue in their own lives, it could be harmful. Most people do not have the ability to meaningfully and sustainably impact their daily air pollution exposure through individual action, whether through technological solutions or changing their daily routines."

Renovating buildings to make them more energy efficient

Renovation of buildings to make them more energy efficient is a key plank of the European Green Deal.[296]

Mr Casares said, "We have an opportunity to massively reduce this carbon footprint by changing the insulation and heating of buildings." Buildings account for 40% of Europe's energy consumption and 36% of greenhouse gas emissions from energy.[297] Approximately 75% of buildings in the EU are not considered energy efficient, yet only 1% undergoes a renovation each year.[298]

The EU's "Renovation Wave" building strategy, launched in October 2020, aims to improve the energy performance of all types of buildings by doubling renovation rates in the next ten years.[299] By 2030, 35m buildings could be renovated and up to 160,000 additional green jobs created in the construction sector by the strategy.[300]

With nearly 34m Europeans unable to afford to keep their homes heated, public policies to promote energy efficient renovation are also a response to energy poverty, which will support the health and wellbeing of people and help them reduce their energy bills.[301]

Around €275bn of additional investment in building renovation is needed every year to achieve the proposed 55% climate target by 2030.[302] Building projects under the

[296] European Commission. Renovation Wave. 2020. https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
[297] European Commission. Renovation Wave: doubling the renovation rate to cut emissions, boost recovery and reduce energy poverty. 14 Oct 2020. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835
[298] European Commission. Renovation Wave. 2020. https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en
[299] European Commission. A Renovation Wave for Europe—greening our buildings, creating jobs, improving lives. 14 Oct 2020. https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf
[300] European Commission. Renovation Wave: doubling the renovation rate to cut emissions, boost recovery and reduce energy poverty. 14 Oct 2020. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835
[301] Ibid.
[302] European Commission. Questions and answers on the Renovation Wave. 14 Oct 2020. https://ec.europa.eu/commission/presscorner/detail/en/QANDA_20_1836

Renovation Wave will be funded from multiple sources, including EU grants, national public funds and the private sector.[303] The European Commission is also reviewing its energy efficiency directive and will set new, more ambitious targets, Mr Casares added.[304]

But our advisory board and interviewees emphasised that it is essential to consider air quality when improving the energy efficiency of homes. Studies have shown that new-build homes have poor air quality because they are so air tight.[305]

"Essentially it's about making sure that when people undertake home energy efficiency installations, they provide enough ventilation," Dr Milner said. "Things like vents and extractor fans need to be installed at the same time and, where appropriate, mechanical ventilation systems so that if there's any reduction in air exchange with the outside, you compensate for that by fitting other measures."

It is not just improving homes that will improve the quality of life and health of poorer communities. Research has shown that acting on carbon not only improves overall public health, it also creates jobs, enhances productivity and cuts energy bills, and that the greatest benefits will be experienced by low-income urban residents.[306]

Populations in lower socioeconomic groups are at greater risk from the impacts of climate change because they are more likely to live in the most polluted urban areas, in poorer and overcrowded housing, and to have poorer overall general health.

2.3 Policy interventions in the healthcare sector

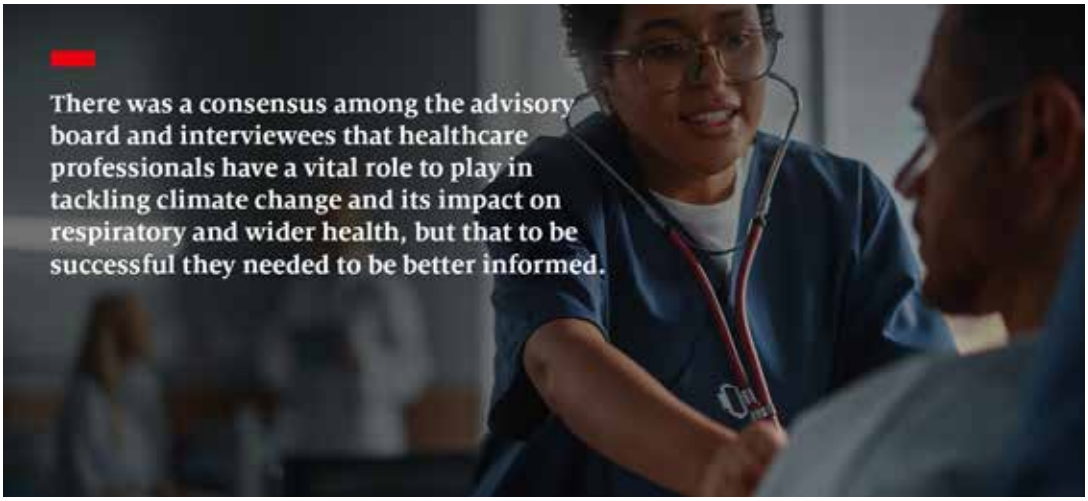
Healthcare professionals have an important role to play in minimising the damaging impact of climate change on health. They can advise vulnerable people, especially those with living with chronic respiratory and other conditions, on protecting themselves during times of peak emissions and extreme weather events. They can also help effect change as trusted and educated members of society by advocating for action on climate change through reducing emissions.

However, while some healthcare professionals are engaged with climate change and its impact on respiratory and wider health, experts believe that many lack the knowledge and the skills to get involved.

Improve education of healthcare professionals on the impact of air quality and climate change on lung health

There was a consensus among the advisory board and interviewees that healthcare professionals have a vital role to play in tackling climate change and its impact on respiratory and wider health, but that to be successful they needed to be better informed. As a result, they want to see climate change

[303] Ibid.
[304] European Commission. Energy efficiency directive. 15 July 2021. https://ec.europa.eu/energy/topics/energy-efficiency/targets-directive-and-rules/energy-efficiency-directive_en
[305] Ministry of Housing, Communities and Local Government. Ventilation and indoor air quality in new homes. 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/835208/Research_-_ventilation_and_indoor_air_quality.pdf
[306] Gouldson A, Sudmant A, Khreis H, et al. The economic and social benefits of low-carbon cities: a systematic review of the evidence. London and Washington, DC: Coalition for Urban Transitions; 2018. Available from: http://newclimateeconomy.report/workingpapers/wp-content/uploads/sites/5/2018/06/The-Economic-and-Social-Benefits-of-Low-Carbon-Cities-A-systematic-review-of-the-evidence.pdf



and its health impacts embedded in medical and healthcare curriculums.

Mr Kelly said that all medical and healthcare training programmes should include modules that incorporate health and climate together "to create a consciousness and linkage, which is so important".

Research shows that currently there is little attention in medical curricula to how climate change impacts respiratory and wider health.[307,308] An international survey found that even in schools of public health, climate change and its repercussions for health were absent in more than a third of curricula.[309] There is growing recognition within the medical profession of the importance of including climate change in curricula, and calls for action.[310,311]

"Even where healthcare professionals have an understanding that climate change caused by humans is harming health, it is not very specific, and often they think there is very little they can do about it," Mr Sanchez Martinez said. "There are perceived barriers—time constraints, lack of knowledge, a lack of support from their peers—and a view that their intervention wouldn't be very effective, that it would not make a difference."

In 2020, the Clean Air Fund questioned a range of healthcare professionals, including respiratory specialists, GPs, nurses, pharmacists, paediatricians and cardiologists, in five countries about their knowledge, role and actions in mitigating and adapting against climate change—200 each in the UK, India, Bangladesh, Mexico and Ethiopia.[312]

[307] Lal A, Walsh E, Weatherell A et al. Climate change education in public health and medical curricula in Australian and New Zealand universities: a mixed methods study of barriers and areas for further action. medRxiv. 2021.
[308] Maxwell J, Blashki G. Teaching about climate change in medical education: an opportunity. J Public Health Res. 2016;5(1):673.
[309] Orhan R, Middleton J, Krafft T et al. Climate action at public health schools in the European region. Int J Environ Res Public Health. 2021;18(4):1518.
[310] Association of Accredited Public Policy Advocates to the European Union. Climate change medical advocacy. 20 Jun 2021. http://www.aalep.eu/climate-change-medical-advocacy
[311] Rabin BM, Laney EB, Philipsborn RP. The unique role of medical students in catalyzing climate change education. J Med Educ Curric Dev. 2020;7:2382120520957653.
[312] Clean Air Fund. How to inspire the healthcare community to act on air pollution. 2021. https://www.cleanairfund.org/wp-content/uploads/2021/05/CAF_HealthCommunitiesResearch_MAY05_compressed.pdf

The responses from the UK showed that 71% had witnessed the health-related consequences of air pollution and 50% in their patients, but only 38% had taken any action on pollution, such as advising patients how to protect themselves, sharing information and knowledge, or attempting to influence government policy.[313] The proportion in the UK was lower than in the other four countries, where health professionals were more likely to have been exposed to the health consequences of air pollution, suggesting that personal experience and thus awareness spurred them into action.[314]

While healthcare professionals in the UK were more likely to have the means to be able to act than those in other countries, the researchers concluded that they didn't make it a priority and that air pollution issues requires greater prominence and a sense of urgency.[315] The researchers recommended the following to encourage healthcare professionals to act in the UK:

- The consequences of air pollution should be made more visible and measurable.
- More evidence on the impact of climate change on respiratory and wider health should be generated and circulated.
- Guidance on addressing the health consequences of air pollution should be embedded into health systems.[316]

Conduct research to increase our understanding of the impact of climate change and air quality on lung health

A robust evidence base is needed for healthcare professionals to be fully engaged with climate change and its repercussions for lung and wider health. There is a need for further research and data to strengthen the evidence on the links and the impact on Europe.

"Research on the links between climate change and adverse health outcomes needs to be fast tracked," said Dr Milner. "Essentially, we've got to do this now, it's kind of now or never. One of the problems we have in research is that it can take many years to get funding, perform the research and publish the results. We really need to implement most climate change interventions within the next decade, so we've got to find new ways of undertaking this research very quickly."

The European Commission and the EEA have created a European Climate and Health Observatory[317] to boost research into climate-related diseases. It plans to publish an annual report on climate change and health in Europe in cooperation with the Lancet Countdown, which is a collaboration of more than 120 global experts, including climate scientists, economists and public health professionals, which monitors 43 indicators (in five areas), including many relevant for respiratory health,

[313] Ibid.
[314] Ibid.
[315] Ibid.
[316] Ibid.
[317] European Climate and Health Observatory. A new EU adaptation strategy. 2021. Available from: https://climate-adapt.eea.europa.eu/observatory/policy-context/european-policy-framework/eu-adaptation-policy

to track the effects of climate change on health.[318]

Health professionals can help raise awareness of the effects of climate change and air pollution on lung health, particularly amongst patients most vulnerable to their effects

Once they understand the impact climate change can have on lung and overall health, healthcare professionals are ideally placed to engage with their patients, particularly those living with chronic lung conditions such as asthma and COPD, on how they can protect themselves from exacerbations when pollution and/or pollen levels rise, and during extreme weather events such as storms and heatwaves.

Potential interventions include educating at-risk individuals to avoid going outside on high air pollution/pollen days and, if they must go outside, to wear a mask. Healthcare professionals can also urge at-risk individuals to stay indoors during heatwaves, keep curtains and blinds shut, and consider use of an air-cooling system, the advisory board and interviewees said.

Approaches to minimising exposure to and the effects of air pollution should be considered part of patients' medical care. Healthcare professionals should, in the plans for people living with asthma, formally write recommendations such as avoiding exercising outdoors and staying indoors on days with high levels of air pollution.[319]

Encouraging patients, particularly those with lung conditions, to consider things like the levels of particulate matter or pollen can make a real difference to their health, said Mr Sanchez Martinez. "The use of pollen and pollution indicators has become more mainstream, but it's something that healthcare professionals can help their patients become a lot more aware of."

It is not just how to act during high levels of air pollution and pollen that healthcare

[318] Lancet Countdown. The 2020 report. Available from: https://www.lancetcountdown.org/2020-report/
[319] NICE. Asthma. QS25. London: National Institute for Clinical Evidence; 20 Sep 2018. https://www.nice.org.uk/guidance/qs25/chapter/Quality-statement-2-Written-personalised-action-plan

professionals can provide advice on but also extreme temperatures. The WHO Regional Office for Europe and the European Commission through their EuroHeat project has recommended that all countries have heat-health action plans in place that contain eight core elements, including governance of a public health response, an accurate and timely alert system, and proper monitoring and evaluation of these plans.[320,321] Warnings of an impending heatwave can then be cascaded through the health system so that the most vulnerable patients can be given advice on how to stay safe. The systems adopted to alert patients vary from passive communication approaches via media releases to targeted alerts sent to specific vulnerable patients.[322]

The advisory board and interviewees also emphasised the importance of encouraging patients to quit smoking, in line with the WHO Framework Convention on Tobacco Control, because tobacco is still a major cause of lung disease and smokers will be especially vulnerable to the health implications of climate change.[323]

Healthcare professionals can help effect national/international action on climate change

"Without the active advocacy of healthcare practitioners in this, we have little hope of gathering political attention," Mr Sanchez Martinez said. "They are consistently the most trusted voices in society, and rightly so, and their views carry weight, and that's going to be even more the case after this covid-19 pandemic. If they could lead on the advocacy, that would make a huge difference."

Ms Cavalieri of the Climate and Clean Air Coalition has been working with the WHO for more than five years trying to raise the profile and the input of public health and the healthcare sector on climate change issues.

"The health sector is missing almost all of the time from the conversation on climate change, and if we had a stronger presence, I think that things would move more quickly, because once people realise the public health implications, they're much more likely to act," she said.

Along with the UN Environment Programme and the World Bank, the WHO and Climate and Clean Air Coalition have launched the BreatheLife campaign which is focused on connecting public health, air pollution and climate change.[324] It encourages governments, health organisations, cities and individuals to make a commitment to reach WHO air quality guidelines by 2030. It brings public health and climate change expertise with guidance on implementing solutions to air pollution in support of global development goals and provides a forum for sharing experience, ideas and best practice.[325] More than 15 European cities, countries or regions (out of 74 globally)

[320] WHO. Heat and health in the WHO European Region: updated evidence for effective prevention. 2021. https://www.euro.who.int/en/publications/abstracts/heat-and-health-in-the-who-european-region-updated-evidence-for-effective-prevention-2021
[321] Climate-ADAPT. EuroHEAT. Improving public health responses to extreme weather/heat-waves: summary for policy-makers. Available from: https://climate-adapt.eea.europa.eu/metadata/publications/euroheat-improving-public-health-responses-to-extreme-weather-heat-waves-2013-summary-for-policy-makers
[322] Climate-ADAPT. Heat health action plans. Available from: https://climate-adapt.eea.europa.eu/metadata/adaptation-options/heat-health-action-plans
[323] WHO. WHO Framework Convention on Tobacco Control. 2003. Available from: https://www.who.int/fctc/text_download/en/
[324] BreatheLife. https://breathelife2030.org/solutions/health-sector-leadership/
[325] BreatheLife. https://breathelife2030.org/about/

are part of the network and have committed to bring air quality to safe levels by 2030.

"We're going to look at all of the sources, including transport, waste and agriculture, and we're going to train health professionals in our cities to understand the data and to be able to do health impact assessments, and include air pollution in that health impact assessment," Ms Cavalieri said.

Organisations representing doctors, including the European Respiratory Society (ERS), the largest scientific and clinical body in respiratory medicine in Europe, are also highlighting the need to act on climate change. For example, on 5 May 2021, the organisation hosted a discussion on climate change and asthma, where it launched a new statement.[326]

The ERS Environment and Health Committee issues comments after landmark climate summits and has participated in the UN Framework Convention on Climate Change in Marrakech as part of the Health and Environment Alliance.[327] The committee has said it strongly supports interventions to reduce the health effects of air pollution through national and supranational legislation on limit values for emissions and emission control.

A working group of the ERS committee produced the "ten principles for climate, environment and respiratory health,"[328] which says climate change represents a "massive threat" to respiratory health. The ERS has called on Europe to divest from fossil fuels and invest in green fuels and technologies, take policy measures to reduce diesel emissions and adopt and enforce WHO standards on air quality as EU limits.

The European Federation of Allergy and Airways Diseases Patients' Associations has been pushing for more action on climate change and lung health. In August 2020, it responded to the consultation on Europe's climate change adaptation.[329] Some of the actions it recommended to prevent climate change–related diseases included financing studies linking climatology with environmental health diseases, strengthening emergency alert systems on climate change events on allergy and respiratory health, and citizen empowerment.

Many respiratory societies and patient groups are part of the "Breathe Vision for 2030" campaign, which launched in January 2021[330] with the message that "a vision to reduce air pollution and to tackle the climate change emergency from a European level will make it possible for people to make healthy choices."[331] It advocates that by 2030, all Europeans should be able to enjoy clean air and that air standards would be no longer fragmented and neglected at the national level.

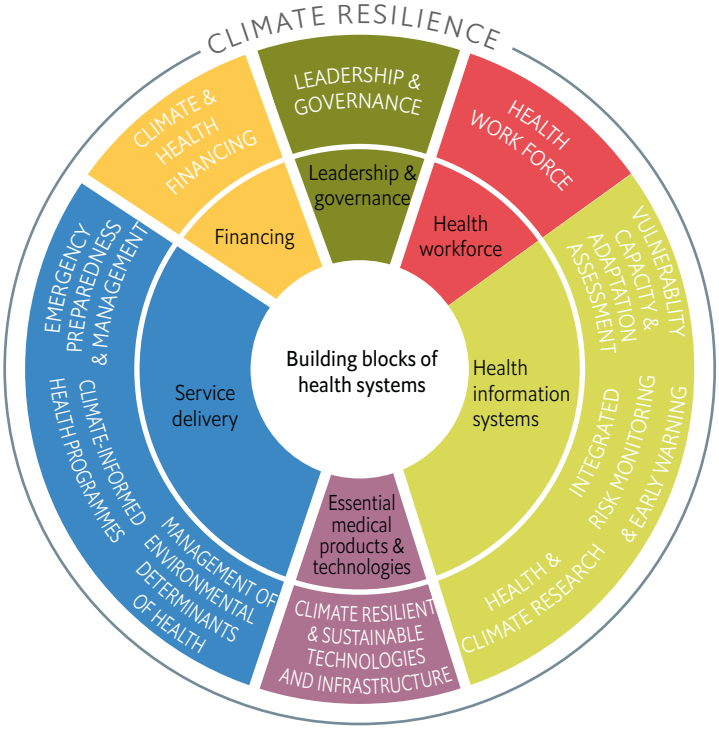
[326] European Respiratory Society. European Respiratory Society position statement on asthma and the environment. May 2021. Available from: https://mk0ersnetorgsavg5whs.kinstacdn.com/wp-content/uploads/2021/04/ERS-position-statement-on-asthma-and-the-environment-5-May-2021.pdf
[327] European Respiratory Society. ERS Environment and Health Committee at international climate change negotiations. 2016. https://www.ersnet.org/news-and-features/news/ers-environment-and-health-committee-at-international-climate-change-negotiations/
[328] Barry M, Annesi-Maesano I. Ten principles for climate, environment and respiratory health. Eur Respir J 2017;50(6):1701912.
[329] European Federation of Allergy and Airways Diseases Patients' Associations. EFA's response to the consultation Adapting to Climate Change–EU Strategy communication (Directorate General for Climate Action). Aug 2020. Available from: https://www.efanet.org/images/2021/EFA_response_to_EC_consultation_on_an_EU_Climate_Change_Adaptation_Strategy.pdf
[330] Breathe Vision. Respiratory patient groups launch the Breathe Vision for 2030. 2021. https://breathevision.eu/news/77-read-the-event-report-respiratory-patient-groups-launch-the-breathe-vision-for-2030
[331] European Lung Health Group. Breathe Vision for 2030. Jan 2021. Available from: https://breathevision.eu/images/Breathe_Vision_for_2030_Vision_Paper.pdf

Build climate resilient health systems

The WHO has warned that climate change poses potentially the greatest threat to global health in the 21st century.[332]

The WHO believes essential health services will be the key to reducing outbreaks of infectious diseases and non-communicable diseases (for example, chronic respiratory diseases through clean energy and technologies in households). In 2015, the WHO published its "operational framework for building climate resilient health systems,"[333] which provides guidance on how health systems can better protect health in an "unstable and changing climate". The WHO thinks that, by implementing its ten components, health authorities will be better able to prevent, prepare for and manage climate-related health risks (Figure 22).

Figure 22: The 10 parts to the WHO operational framework for building climate resilient health systems



Source: WHO; https://www.who.int/publications/i/item/quality-criteria-health-national-adaptation-plans.

[332] WHO. Health, environment and climate change. Report by the director-general. 9 Apr 2018. Available from: https://apps.who.int/iris/bitstream/handle/10665/276332/A71_10-en.pdf
[333] WHO. Operational framework for building climate resilient health systems. Geneva: World Health Organization; 2015. Available from: https://apps.who.int/iris/bitstream/handle/10665/189951/9789241565073_eng.pdf?sequence=1&isAllowed=y

In its 2017/18 WHO Health and Climate Change Survey,[334] the WHO found about 50% of countries surveyed (51 out of 101) had a national health and climate change strategy or plan, although a qualitative analysis indicated their content and scope varied widely.

Most of the plans (25 out of 36 country respondents)[335] were approved or updated in the past five years, indicating a recognition of the urgency to protect population health from climate change. A majority of countries reported only moderate or low levels of implementation of their plans with financing being cited as the most common barrier.

The WHO also found multisectoral collaboration on health and climate change policy was evident yet progress was uneven. Collaboration on health and climate policy was greatest between the health sector and the water, sanitation and wastewater sector, followed by agriculture and social services. Less than a quarter of the countries reported having an agreement in place between the health sector and the transportation, electricity generation or household energy sectors.

In February 2021, the WHO published its "Quality Criteria for Health National Adaptation Plans"[336] to help countries build climate-resilient health systems. The WHO recommends that countries be ambitious in the coverage of climate-sensitive health risks and identify priorities and adaptation actions to address these risks.

The advisory board acknowledged the importance of supporting all countries, not just Europe, to strengthen their health systems' resilience against the impacts of climate change and to support them to meet UN sustainable development goals. They noted that, as with mitigation strategies, if adaptive strategies are not implemented in all countries, there will be repercussions for neighbouring countries and other regions of the world.

In May 2021, the international Adaptation Action Coalition (AAC) launched the Climate Resilient Health Systems Initiative to further action on addressing the health impacts of climate change while strengthening health resilience. The initiative has a clear vision: to ensure that by 2030 all health systems worldwide have strengthened resilience against climate impacts.[337]

The AAC was founded in January 2021 and aims to build momentum and accelerate action to adapt and build resilience to the impacts of climate change.[338] The coalition was developed by the UK in partnership with Egypt, Bangladesh, Malawi, the Netherlands, Saint Lucia and the UN Development Programme in response to the 2019 UN Climate Action Summit 'Call for Action on Adaptation and Resilience'.[339,340]

[334] WHO. WHO health and climate change survey report: tracking global progress. Geneva: World Health Organization; 2019. https://apps.who.int/iris/bitstream/handle/10665/329972/WHO-CED-PHE-EPE-19.11-eng.pdf?ua=1
[335] Although 51 countries reported that a national health strategy/plan had been completed, the approval process by the national health service was ongoing for 10 countries, according to the WHO report.
https://apps.who.int/iris/bitstream/handle/10665/329972/WHO-CED-PHE-EPE-19.11-eng.pdf?ua=1
[336] WHO. Quality criteria for health national adaptation plans. 9 Feb 2021. Available from: https://www.who.int/publications/i/item/quality-criteria-health-national-adaptation-plans
[337] WHO. Adaptation Action Coalition health launch. Building climate resilient health systems. 6 May 2021. Available from: https://www.who.int/news-room/events/detail/2021/05/06/default-calendar/adaptation-action-coalition-health-launch
[338] Ibid.
[339] Adaptation Action Coalition. A call for action: raising ambition for climate adaptation and resilience. 3 Feb 2021. Available from: https://www.adaptation-undp.org/sites/default/files/uploaded-images/call_for_action_on_adaptation_and_resilience_v_3_feb_2021.pdf
[340] UK Foreign, Commonwealth and Development Office. Adaptation Action Coalition: an overview. 15 Jul 2021. Available from: https://www.gov.uk/government/publications/adaptation-action-coalition-an-overview

Governments can join the initiative by committing to conduct climate change and health vulnerability and adaptation assessments; develop a Health National Adaptation Plan; or by allocating, or applying for, climate finance for health action. In addition to commitments under the AAC, governments are encouraged to develop an action plan or roadmap for achieving a sustainable low-carbon health system that minimises climate impacts and increases resilience.[341]

Healthcare sector as exemplar to net-zero carbon emissions to encourage others

If healthcare was a country, it would be the fifth biggest emitter on the planet.[342] The world's healthcare systems are responsible for 4% of global CO_2 emissions,[343] more than aviation or shipping.[344] Healthcare systems also emit a significant amount of short-lived yet potent climate pollutants, including black carbon, methane, HFCs and anaesthetic gases.[345]

More specifically, healthcare services and medical supply chains generate 4.4% of greenhouse gases, 2.8% of PM, 3.4% of NOx and 3.6% of SO_2.[346]

Greener healthcare systems can play a significant role in tackling climate change, not only by reducing their own emissions, which should be a priority for a sector based on the principle of "first do no harm," but also leading by example, showing other sectors what can be done.[347]

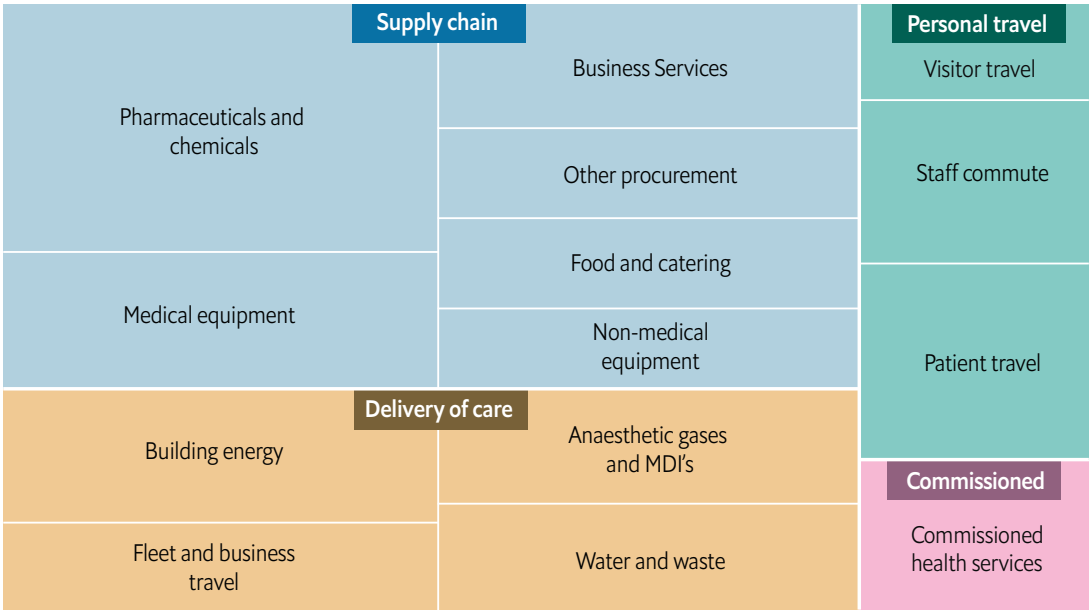
[341] WHO. Adaptation Action Coalition health launch. Building climate resilient health systems. 6 May 2021. Available from: https://www.who.int/news-room/events/detail/2021/05/06/default-calendar/adaptation-action-coalition-health-launch
[342] Healthcare Without Harm. Health care climate footprint report. Sep 2019. Available from: https://noharm-global.org/documents/health-care-climate-footprint-report
[343] Pichler PP, Jaccard IS, Weisz U et al. International comparison of health care carbon footprints. Environ Res Lett. 2019;14(6).
[344] Metzke R. First do no harm. Why healthcare needs to change. World Economic Forum; 16 Sep 2019. https://www.weforum.org/agenda/2019/09/health-climate-change-sustainability/
[345] Ibid.
[346] Lenzen M, Malik A, Li M et al. The environmental footprint of health care: a global assessment. The Lancet Planet Health 2020;4(7):E271-9.
[347] Metzke R. First do no harm. Why healthcare needs to change. World Economic Forum; 16 Sep 2019. https://www.weforum.org/agenda/2019/09/health-climate-change-sustainability/

Emissions related to healthcare services cover:

- direct emissions from healthcare facilities in providing care, including the energy efficiency of buildings and ambulances;
- emissions from purchased power and commissioned services;
- emissions from staff commuting;
- emissions from the supply chain of all consumables and equipment used in the health service; and
- the direct impact of some pharmaceuticals that are potent greenhouse gases.[348]

Pharmaceuticals which are potent greenhouse gases include anaesthetics (sevoflurane, isoflurane, and desflurane) and nitrous oxide (N_2O), as well as chlorofluorocarbon or hydrofluorocarbon propellants used in some metered dose inhalers (MDIs).[349] Pressurised metered dose inhalers are the largest contributor of GHG emissions from pharmaceuticals.[350] Under the Montreal Protocol, ozone-depleting chlorofluorocarbons were banned, and there was a transition to HFCs. Although the global warming potential of HFCs is significantly lower than chlorofluorocarbons, it is still considered high. Replacing the current propellants HFC-134a and HFC-227ea in

Figure 23: Contributions of different sectors to the greenhouse gas emissions of the National Health Service (NHS) in England, 2019



Source: https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30271-0/fulltext#articleInformation.

[348] Tennison I, Roschnik S, Ashby B et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. Lancet Planet Health. 2020;5(2):E84-92.
[349] Ibid.
[350] Jeswani HK, Azapagic A. Life cycle environmental impacts of inhalers. J Clean Prod. 2019;237:117733.

pressurised MDIs with lower global warming potential propellants such as HFC-152a, which have a greater than 90% lower carbon footprint, or the prescribing of dry powder inhalers would reduce the environmental impact of these treatments.[351] The ERS advocates this approach when clinically appropriate and acceptable to patients.[352] Other carbon-reducing initiatives can also be introduced within the healthcare system and patient pathways for respiratory conditions, which may also help to improve the efficiency of treatments and reduce the over-reliance on some treatments.[353]

Forty healthcare institutions on six continents, representing more than 3,000 healthcare facilities in 18 countries, have signed on to the Global Healthcare Without Harm Race to Zero initiative and committed to achieving net-zero emissions by 2050. This includes 14 healthcare institutions in Europe.[354]

In England, the whole national health system—the NHS—has been working since 2008 to reduce its carbon footprint (Figure 23).[355] As part of its greener strategy, in 2020 the NHS pledged to become the world's first carbon-neutral health system and to achieve this for its services by 2040 and its wider supply chain by 2045.[356]

In 2019, CO_2 emissions linked to the NHS in England totalled 25 megatonnes, which was 26% lower than in 1990, and a decrease of 64% in the emissions per inpatient finished admission episode. Of the 2019 footprint of the NHS, 62% came from the supply chain, 24% from the direct delivery of care, 10% from staff commute and patient and visitor travel, and 4% from private health and care services commissioned by the NHS.[357]

2.4 Policy interventions to connect the public, civil society and media

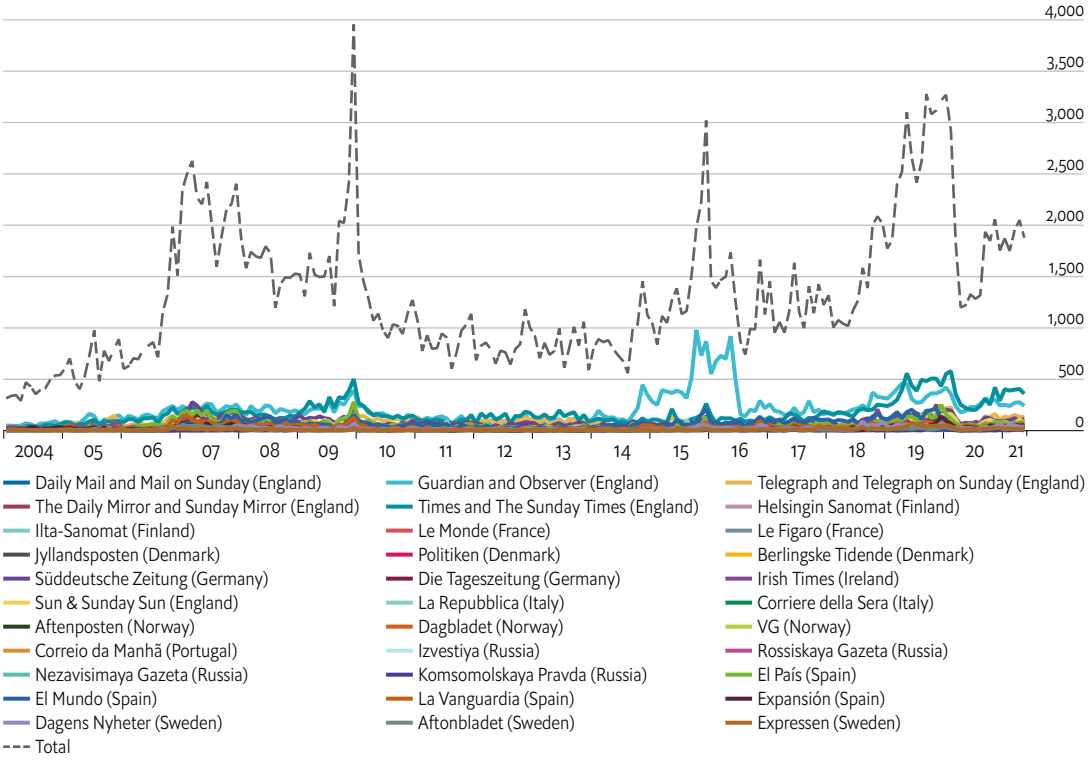
Societies need to act on climate change to protect the health, especially respiratory health, of all people across the globe. To effect change that impacts at a population level requires policies and actions at a similar scale.

Policymakers at the global, European, national and local level must therefore engage and win the support of stakeholders, citizens, civil society and the media if they are to be successful.

The evidence suggests that the support exists in Europe. There has been growing political and medical recognition of the climate change emergency, and the actions of activists from Greta Thunberg to Extinction Rebellion, as well as high-profile court cases (see UK case study) have increased the media presence of climate change issues over the last 20 years (Figure 24), which has led to increased public awareness.

[351] Ibid.
[352] European Respiratory Society. European Respiratory Society position statement on asthma and the environment. Available from: https://mk0ersnetorgsavg5whs.kinstacdn.com/wp-content/uploads/2021/04/ERS-position-statement-on-asthma-and-the-environment-5-May-2021.pdf
[353] Usmani OS Scullion J Keeley D. Our planet or our patients—is the sky the limit for inhaler choice? Lancet Respir Med. 2019;7:11-3
[354] Healthcare Without Harm. Available from: https://noharm-global.org/articles/news/global/race-zero-health-care-sector-%e2%80%93-join-us
[355] Tennison I, Roschnik S, Ashby B et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. Lancet Planet Health. 2020;5(2):E84-92.
[356] NHS England and NHS Improvement. Delivering a "net zero" National Health Service. 2020. https://www.england.nhs.uk/greenernhs/wp-content/uploads/sites/51/2020/10/delivering-a-net-zero-national-health-service.pdf.
[357] Tennison I, Roschnik S, Ashby B et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. Lancet Planet Health 2020;5(2):E84-92.

Figure 24: European newspaper coverage of climate change or global warming, 2004-21
(number)



Source: https: //sciencepolicy.colorado.edu/icecaps/research/media_coverage/europe/index.html .

In January 2021, the UN Development Programme published the results of what is believed to be the largest ever survey of people's views on climate change. The survey, conducted across 50 countries during the covid-19 pandemic, found that 64% of the 1.2m respondents believe climate change is an emergency—presenting a clear mandate for decision makers to step up on ambition and action.[358] Support was even higher in Europe: 72% in western Europe and North America and 65% in eastern Europe and Central Asia.[359] Younger people (under 18) were also more likely to say climate change is an emergency, indicating that the support and demands for action are only likely to get stronger.[360]

Mr Casares said that there were some countries, particularly in eastern Europe, where there was more to do in terms of increasing population awareness of the impact of climate change on respiratory and wider health in order for action.

"In some countries, the conservative parties are not supporting this climate ambition and the concern of the population is lower," he said. "In countries like Hungary, climate change

[358] UNDP. World's largest survey of public opinion on climate change: a majority of people call for wide-ranging action. 27 Jan 2021. https://www.undp.org/press-releases/worlds-largest-survey-public-opinion-climate-change-majority-people-call-wide
[359] UNDP. The peoples' climate vote. 26 Jan 2021. https://www.undp.org/publications/peoples-climate-vote
[360] UNDP. World's largest survey of public opinion on climate change: a majority of people call for wide-ranging action. 27 Jan 2021. https://www.undp.org/press-releases/worlds-largest-survey-public-opinion-climate-change-majority-people-call-wide

is not so high on the agenda. The problem with a growing economy is how to say to the people, don't do that because it's bad for the climate."

People living in eastern Europe, where coal is still relied on to generate power and heat homes, are especially at risk of the respiratory and other health effects of pollution, Ms Stauffer pointed out. Thus they have the most to gain from action on climate change. "The environmental health burden in eastern Europe is greater [than western Europe], which means there should be a greater willingness to transform because there is a huge potential to better protect the health of the population through strong environmental and climate measures," she said.

People should lobby their political representatives for change

Experts told us that consumers can challenge their political leaders on climate change. Mr Sanchez Martinez said he is often asked by people what they can do to improve their sustainability. "They think that I'm going to tell them to sort out their garbage and recycle. I tell them to get the phone number of their political representative and to pester them about the environmental issues that matter. "Efforts are better directed at making political representatives aware that this is an issue for the constituency, and that they are not happy about it. That is the way to go about it. There's no other way." The impact of individuals, even as consumers, is "very limited", he explained. "The systems themselves are biased towards a lack of sustainability, and that's what needs to be changed."

While the European Green Deal is seen by some as "radical", he added, "the truth is that it falls short of what should be done and how fast. However many plastic bottles you recycle, if the whole system for producing them and using them is still there, it's not a waste of time, but it's not going to have much of an impact. It's like the electricity you use, and the fact that you don't have a choice to make it more renewable, even if you had to pay more."

To make a real impact on climate change, it is larger system issues, such as environmental standards for procurement that need to be acted on, and this needs to be done at a political level and within large public bodies, he said.

Experts think that sharing information transparently will help empower people to demand action.

UK case study: Ella's mother's campaign for clean air

In 2020, Ella Adoo-Kissi-Debrah became the first person in the UK to have her cause of death listed as air pollution in a landmark decision after a campaign by her mother.[361] Rosamund Adoo-Kissi-Debrah drew attention to how poor air quality had contributed to her daughter's death and to force action on air pollution to protect other children.[362]

Ella was nine when she died following an asthma attack in 2013. She lived near the South Circular Road in Lewisham, south-east London, and had been admitted to hospital 27 times in the previous three years.[363]

An inquest at Southwark Coroner's Court in December 2020 found that exposure to excessive levels of air pollution "made a material contribution" to Ella's death. The coroner Philip Barlow said levels of nitrogen dioxide near Ella's home exceeded WHO and EU guidelines.[364]

He said there was a "recognised failure to reduce the levels of nitrogen dioxide, which possibly contributed to her death", and "a lack of information given to Ella's mother that possibly contributed to her death".[365]

On Clean Air Day, 17 June 2021, the UK government announced wide-ranging new measures to protect against air pollution.[366] These include:

- Increasing public awareness of air pollution, including a review of existing information sources and more specific messaging for different population groups. This will help health professionals in advising patients when poor air quality is forecast. The government will also look at working with charities on longer-term campaigns aimed at vulnerable groups.
- Setting new legal targets for $PM_{2.5}$ (fine particulate matter) and other pollutants by October 2022.
- Funding local authorities to improve public awareness about the risks of air pollution in their communities and identifying ways to spread air quality information more widely with broadcasters, social media firms and apps with clear advice that people can act on. It will also consider the effectiveness of setting up a new national SMS alert system.
- Continuing work by the NHS on a more systematic approach to asthma management. This will include identifying environmental triggers and promoting more personalised care.
- Working with the medical and nursing Royal Colleges and others to support any work they may be considering to engage their members, including changes to undergraduate and postgraduate teaching.

[361] Booth, R. Mother wants inquiry into role of pollution in daughter's asthma death. The Guardian, 5 Jun 2016. https://www.theguardian.com/society/2016/jun/05/mother-inquiry-air-pollution-daughter-asthma-death
[362] Ella Adoo-Kissi-Debrah: Air pollution a factor in girl's death, inquest finds. BBC News, 16 Dec 2020. https://www.bbc.co.uk/news/uk-england-london-55330945
[363] Ibid.
[364] Ibid.
[365] Ibid.
[366] UK Department for Environment, Food & Rural Affairs. Government responds to Coroner after Ella Kissi-Debrah inquest. 17 Jun 2021. https://www.gov.uk/government/news/government-responds-to-coroner-after-ella-kissi-debrah-inquest

People should try to protect themselves during air pollution peaks and extreme weather events with supportive healthcare systems

Increased air pollution or pollen levels, and extreme weather events such as heatwaves will make people living with chronic lung conditions more vulnerable to exacerbations. With the support of healthcare systems, people should therefore do what they can to protect themselves to keep their condition from deteriorating.

Experts told us that people should avoid exercising outside during peaks of air pollution and pollen and stay indoors if possible. If they must go outdoors, they should consider wearing a mask. The same precautions are recommended for people living with asthma who also have pollen allergens when a storm is looming because this puts them at increased risk of severe asthma attacks.

Similar precautions should be taken during heatwaves for those most vulnerable to the effects, particularly the elderly. These people should stay indoors and try to keep cool, perhaps by drawing the curtains or blinds and if necessary using fans or air-conditioning units.

Although general awareness of the risks of air pollution and heat has grown among people in Europe, due to publicity about climate change and increasing numbers of heatwaves, those most vulnerable to air pollution, pollen and heat should receive tailored advice from a health professional.

Health professionals can also encourage their patients to make changes that not only improve their own health but also have an impact on the emissions they produce. Examples are not burning wood or coal at home and opting for active transport.

For people most at risk, the self-care actions that they should take during specific circumstances that trigger exacerbations of their condition should be written into their formal disease management plan (such as an asthma plan).[367]

[367] NICE. Quality statement 2: written personalised action plan. QS25. 20 Sep 2018. https://www.nice.org.uk/guidance/qs25/chapter/Quality-statement-2-Written-personalised-action-plan

A direct alert system should be in place for when levels of air pollution, pollen or temperatures are expected to rise and put people's respiratory health at risk. There are cascade alert systems within health services, but how they inform the public varies. While many health services will issue press releases to the media, alerts should also specifically target vulnerable patients, experts told us. Targeting such patients with an SMS alert should be easily feasible with electronic patient records, disease registers and the wide availability of mobile phones (around 85% of the population in Europe has a mobile phone).[368]

"London has been really good on issuing alerts when there is peak pollution, but unfortunately, across the EU we have a very patchy picture on what authorities provide, both in terms of information and alerts," Ms Stauffer said. "This is a key issue for respiratory patients."

She said that guidance was needed on when and how these health advisories should be issued, and to standardise the information so they are understandable for the general public.

Approaches to monitoring pollen is also very diverse across Europe. Ms Stauffer said there was a need to bring the monitoring of air pollution and pollen together into an "integrated system" so people can access these data easily.

People should try to improve their respiratory health

People with good lung health will be less vulnerable to the impact of climate change on their respiratory health, the advisory board and interviewees emphasised, so action against climate change should also encompass efforts to improve people's lung health.

It is important that people with chronic lung conditions, such as asthma or COPD, receive appropriate management. Mr Sanchez Martinez said: "If these people don't have access to adequate care, they're going to get to a point where an aggravation by those impacts related to climate change may be fatal."

Efforts against climate change would encourage people to improve their respiratory fitness, which would improve their health and help protect them against the adverse health impacts of climate change.

There is a need for the general public to recognise the science on how climate change is linked to our health and how reducing emissions and really transforming our economies back from this polluting model—a model so heavily dependent on fossil fuels—to one that uses renewable energies, promotes active mobility and has healthier and sustainable food systems, Ms Stauffer said, adding that "the recognition that climate mitigation is ultimately a health necessity."

Professor Kelly is aligned: "More active transport like walking and cycling is not only good for the environment, but it's really good for your health. So that's a real win-win situation."

One positive that could be taken from the covid-19 pandemic that could be built on was that it has "opened people's eyes" to the impact certain changes might have on their lives, he said. With countries in lockdown, emissions from traffic dropped,[369,370,371,372] and

[368] GSMA. The mobile economy Europe. 2018. https://www.gsma.com/mobileeconomy/europe/#:~:text=Smartphone%20adoption%20at%20year-end%202019%2C%20as%20a%20proportion,in%20Europe%2C%20equivalent%20to%2085%25%20of%20the%20population
[369] Venter ZS, Aunan K, Chowdhury S et al. Air pollution declines during COVID-19 lockdowns mitigate the global health burden. Environ Res. 2021;192:110403.
[370] Venter ZS, Aunan K, Chowdhury S et al. COVID-19 lockdowns cause global air pollution declines. Proc Natl Acad Sci U S A. 2020;117(32):18984-18990.
[371] Giani P, Castruccio S, Anav A et al. Short-term and long-term health impacts of air pollution reductions from COVID-19 lockdowns in China and Europe: a modelling study. Lancet Planet Health. 2020;4(10):e474-82.
[372] Brown L, Barnes J, Hayes E. Traffic-related air pollution reduction at UK schools during the covid-19 lockdown. Sci Total Environ. 2021;780:146651.

more people began walking and cycling for exercise and appreciating the environment around them. "They have found it's much more pleasant if you don't have lots of vehicles on the road."

People should try to reduce emissions and live sustainably

People should do their utmost to reduce their carbon footprint and reduce their emissions by looking at the choices they make in areas such as energy usage, transport, food and consumer purchasing, and try to live sustainably.

Tools such as the app Capture[373], which calculates a users' monthly CO_2 targets by asking a series of questions about food and transport, are available to help with this.

But ultimately there is a limit to what individuals alone can do within the systems and choices available to them. These systems are controlled by government, local authorities and the private sector.

People should be encouraged to monitor the emissions they are exposed to

Encouraging people to monitor the air quality around them has several benefits, the advisory board and interviewees pointed out.

Primarily it increases individuals' awareness of climate change and provides them with an indication of when and at which geographical locations they are exposed to the greatest levels of air pollutants. The data collected can also encourage people to adapt their behaviour to avoid times and places with higher air pollution levels, particularly if they are exercising or have a chronic lung condition.

Ms Stauffer said use of such monitors was becoming more popular in Europe. "Many people were disappointed with the official monitoring, so they really wanted to see for themselves what their exposure to pollution is. People can then make informed choices, for example, considering which route to take the kids to school or when to go out."

The data collected can also complement the data gathered by official monitoring sources to increase understanding of pollution peaks and hotspots at a more granular, local level. Some official monitoring sites are not always placed in the most polluted areas, experts told us.

"This is part of citizen science and something that should be supported by decision makers," Ms Stauffer said

[373] Capture. https://www.thecapture.club/

Not only does citizen science raise awareness of the impact of air pollution on individuals' own health, it also prompts them to make the links between air quality and climate change and then to demand change from governments, Mr Chung said.

He said, "As we saw during the covid-19 crisis, you can have clean air pretty quickly. There were massive drops in levels of air pollution in many places, so in terms of political expediency, the political capital for a politician acting on air pollution can happen in their political term, whereas for the actions on climate, it is a politician working beyond 2030 who's going to gain that political capital. That is why I think the link between air quality and climate will be important at the international climate change conference, COP26, in helping drive governments to take action, because while they will be making decisions for the future, they will be acting on air pollution today."

There are many low-cost and easy-to-use devices that can pair with mobile phones to upload data that can support such citizen science initiatives.

There must, however, be some caveats with interpretation of this information since individual devices will not have been calibrated to the same standards as official monitoring devices, experts said. Nevertheless such devices can show trends even if absolute values measured must be considered more cautiously.

Examples of citizen science exercises include CurieuzeNeuzen Vlaanderen,[374] which involved 20,000 people in Belgium, who used passive NO_2 samplers to measure air quality near their homes. The CleanAir@School project involved eight European environment agencies, where citizens monitored air quality around schools in 2018 and 2019, across Europe, using a common approach.[375]

[374] https://curieuzeneuzen.be/ and De Craemer S, Vercauteren J, Fierens F et al. CurieuzeNeuzen: monitoring air quality together with 20,000 citizens. https://www.aivc.org/sites/default/files/D1_S0Opening-06.pdf
[375] European Environment Agency. Citizen science initiative CleanAir@School. https://www.eea.europa.eu/themes/air/urban-air-quality/cleanair-at-school

Conclusion

There is evidence that emissions linked to global warming have an adverse impact on respiratory health, in particular emissions from combustion of fossil fuels and biomass by power stations, industry, homes and vehicles.

The need for action is recognized by the environmental sector and increasingly by the heath sector and the European general public, who are also beginning to demand tougher action. More awareness of climate change's impact on lung health among these groups is vital for effecting change.

There is only so much one engaged individual can do in terms of cutting emissions and living sustainably. Mass change is needed, and most importantly the policies and systems in societies—controlled by governments and public authorities—need to support efforts to reduce emissions and tackle climate change.

Increasing awareness among the health sector and the general public of the need for urgent action on climate change is the path to achieving it by putting pressure on politicians to act.

UK-CHI-2100332 Date of preparation: July 2021

Summary of EIU policy priorities on climate change and lung health

European and national level

Priority areas

- **End burning of fossil fuels**
- **Make improving public health the central goal in climate change policies**
- **Involve all relevant stakeholders in climate change policies**

- Speed up progress on climate change beyond existing targets through legislation and international cooperation
- Act to reduce greenhouse gases and emissions by fostering innovation across all sectors
- Prioritise tackling methane as well as hydrofluorocarbons (encouraging the use of alternatives with a low global warming potential)
- Encourage use of electrical power to support the ultimate switch to clean renewable sources
- Improve interconnectivity of national electricity grids to maximise use of clean renewables
- Remove fossil fuel subsidies and extend carbon pricing to move away from fossil fuels
- Move way from burning wood and biomass as these are associated with high levels of particulate pollution
- Invest in clean energy, green innovation and technology
- Be a leader on climate change issues on the world stage

Environmental and local level

Priority areas

- **Focus on improving air quality, particularly in urban areas where most people live**
- **Ensure air quality data are easily accessible**
- **Promote active transport and public transport powered by clean energy**

- Design cities and transport policies that discourage the use of vehicles with combustion engines
- Issue standardised warnings for high levels of air pollutants and aeroallergens
- Consider air quality metrics alongside energy efficiency in construction/renovation of buildings
- Provide green and traffic-free spaces
- Reduce health inequalities by introducing measures to tackle climate change

Climate change and lung health

Healthcare sector

Priority areas

- **Improve education of healthcare professionals on the impact of air quality and climate change on lung health**
- **Focus attention on high-risk and vulnerable people (older, those living with respiratory conditions)**

- Use health professionals as trusted members of communities to raise awareness of the effects of climate change and air pollution on lung health
- Conduct research to increase our understanding of the impact of climate change and air quality on lung health
- Act as an exemplar in reducing emissions and moving to net-zero carbon emissions to encourage other sectors to follow
- Healthcare professionals are trusted so can help effect national/international action on climate change

Public, civil society and media

Priority area

- **Lobby political representatives to act on climate change locally and at the EU level**

- Bring in measures to boost awareness and action by the public (eg, citizen science approaches using personal air quality monitors can help engage the public)
- Make messages easy to understand for clearer messaging by media
- Grass roots champions and legal challenges can encourage politicians to act on climate change

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